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Seeing Stars in the City – A History of Early Astronomy in Sydney

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Abstract: Mankind has always been fascinated by the apparent movement of the objects in the sky. Initially the stars and planets had a spiritual significance, but later their value as markers of time and aids to navigation came to be recognised. The invention of the telescope four centuries ago enabled people to expand their understanding of these celestial phenomena. Astronomy was the doyen of the sciences by the end of the 18th century, the so-called Age of Reason, when Australia was first settled by Europeans. Thus it is not surprising that it was practised in the new colony from the earliest days. This paper traces an almost unbroken line of notable astronomers in Sydney until the early 20th century.

Keywords: Astronomy, history, meteorology, observatory, Royal Society, Sydney, telescope.

When Galileo Galilei turned his telescope towards the sky in Florence four hundred years ago, and wrote about 'The Starry Messenger', he launched an intellectual revolution that we celebrated in 2009 as the International Year of Astronomy.[1] That occasion makes it an appropriate time to reflect on the achievements of some notable astronomers who continued in the same tradition while working in Sydney during the period before Federation.

Let us begin with a little story:

'*Beyond the horizon, where no one has ever been, there is a beautiful land with grassy valleys and tree-covered hills. The inhabitants of that land are Moons – big, shining globular Moons. They have no arms or legs, but they can move quickly across the grass by rolling over and over. It is a pleasant life in that green, watered land, but sometimes the Moons grow restless, and when night comes they have the urge to explore farther afield and stroll across the sky.*

Only one Moon goes on such a journey at a time. It is a pity that they do not go in company, but they do not know that outside the valley there lives a giant. He catches the wandering Moon, and with his flint knife he cuts a slice from it each night, until after many nights there is nothing left but a number of shining slivers. The giant cuts them up very finely and throws them all over the sky.

They are timid little creatures, these cut-up Moons which have become Stars. During the day, when a Sun goes striding across the sky, they hide. Who knows but that, if they showed themselves then, another giant Sun might not creep out and catch them unawares.'

Adapted from Reed 1993

This is one of the many legends and fables recounted by Aboriginal Australians to explain the existence of the sun, moon and stars. Although the stories vary from locality to locality, indigenous people generally believe that every aspect of the world we know today was created by spirits who once lived in the sky. This spirit dreaming is repeated in the dreamings of the people who now inhabit the earth (Bursill 2007).

Unfortunately most of the stories told by the Eora people who were the original inhabitants of the Sydney region were lost before anthropologists became active in the mid-nineteenth century (Turbet 2001). Nevertheless, the story demonstrates the truism that since earliest times humans have been fascinated by the sky, particularly the night sky, and the apparent movement of the objects which they can see.

The settlers who arrived in 1788 were not simply disinterested observers like Cook and Banks who sailed past in 1770; Val Attenbrow from the Australian Museum has pointed out that 'The colonists impacted on the local way of life from the moment they began clearing the land.' (Attenbrow 2002). Although there are colourful accounts of the life and customs of the local Aborigines written by officers of the First Fleet, we cannot assume that these

[1] Sidereus Nuncius was published in 1610. In 1616 the Catholic Church told Galileo to stop advocating heliocentrism, and banned an earlier book by Copernicus on a similar theme.

reports provide an accurate description of pre-1788 conditions, which may already have been coloured by the new circumstances as well as the authors' own pre-conceptions. Furthermore, the local population of the Sydney region (no more than 3,000 on the best estimate) was devastated by a virulent epidemic the following year, possibly smallpox, leaving few older people with a sound knowledge of their own traditions.

Serious research into local customs began during the nineteenth century, particularly amongst groups that had not had significant contact with Europeans. W.E. Stanbridge studied the original inhabitants of the Victorian mallee around 1857, and noted that the appearance of the major star clusters above the horizon were associated with seasonal events – in effect, a primitive calendar (Stanbridge 1857).

Several anthropologists reported that the brightest stars and constellations, such as the Milky Way and the Southern Cross were given a meaning, although this differed between regions. Writing in the Royal Society of New South Wales *Journal & Proceedings* in 1881, Rev. Peter MacPherson noted similarities between Greek and Aboriginal mythology, for instance in associating the Pleiades with a group of young maidens (MacPherson 1881). Still later, some rock carvings at Manly were interpreted as indicating that the Eora people had some concept of the relative motion of the Earth to the Sun, and that they understood that the Earth revolved. If this was the case, these were concepts that Copernicus (1473–1543), Kepler (1571–1630), Galileo (1564–1642) and Newton (1643–1727) had difficulty in convincing the 'civilised' Old World four centuries ago, at a time when other creation myths prevailed (Ramsay 1932).

Scientific values of rational enquiry became more widely accepted in the eighteenth century, during the period called the Enlightenment or the Age of Reason. At this time France and Britain were the international superpowers, engaged in a rivalry for scientific and territorial discovery. Much of the Pacific Ocean was uncharted, yet a problem faced by all navigators when so distant from their homelands was the difficulty of accurately determining their position. Provided that the skies were reasonably clear, it was relatively easy to fix latitude (North-South) by measuring the angle between the sun and the horizon. Longitude (East-West position) was a more difficult proposition for a ship at sea. The only way of measuring a vessel's speed was to cast a knotted rope overboard and count the number of knots that passed through the bosun's hands in a fixed period, usually determined by an hour-glass. That calculation did not take account of tides or currents, so provided only a rough estimate of distance travelled. Clocks of that era were driven by a pendulum mechanism that could not cope with the motion of a sailing ship and so could not measure elapsed time. Astronomical observations were not very helpful in the southern hemisphere because there were no accurate tables of star positions. It is no wonder that many East Indiamen on their way to Java accidentally bumped into New Holland because the Captain miscalculated his position.

So acute was the problem that a Board of Longitude was established in England in 1714, offering a prize of up to £20,000 to the person who devised an accurate and reliable means of finding longitude at sea. After much experimentation, that honour finally went to John Harrison who developed chronometers that were not affected by motion, and could maintain accurate time for an extended period. Knowing that in one hour, the sun's apparent position has altered by 15 degrees of longitude, it was possible to calculate the distance from a fixed reference point – the Greenwich meridian became the benchmark. Nevertheless, Harrison had great difficulty in collecting the prize, and in fact he never received the full sum promised (Wikipedia 2010)[2].

In 1768 the Royal Society in London petitioned King George III to mount an expedition to observe the Transit of Venus the following year, a phenomenon that would be seen at its best in the South Seas. Lieutenant James Cook was selected by the Admiralty to command HM Bark *Endeavour* while Charles Green, a former assistant to the Astronomer Royal, Rev. Dr

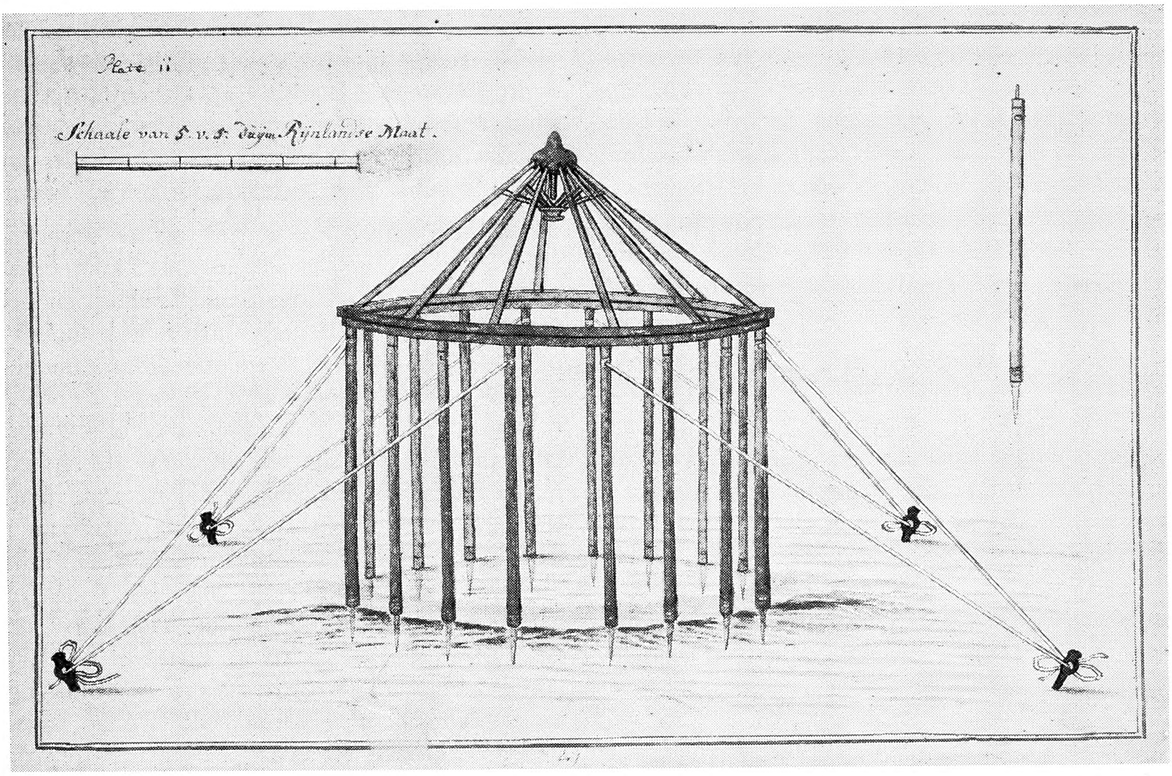
[2] Also see National Maritime Museum website, `http://www.nmm.ac.uk`

Nevil Maskelyne, was appointed by the Royal Society as principal observer. Wealthy young botanist Joseph Banks paid for himself and a retinue of other scientists to secure a place on the voyage.

The Transit of Venus is that rare phenomenon when the planet Venus passes between the Sun and Earth, and therefore appears as a black spot moving across the Sun. It occurs in an unusual pattern; in a pair about eight years apart, and then not again for over a century. The last transit visible from Sydney was in June 2004, the next will be on 6 June 2012, at 8.30 am; thereafter the next will not be until 2117. The significance of the event for astronomers was that if carried out at a number of widely separated locations (77 in this case) it provided a means of calculating the distance between the Earth and the Sun. That distance is now known as the Astronomical Unit – approximately 150 million km. From this information it was hoped that astronomers could deduce the size of the whole solar system (Lomb 2004).

James Cook's skill as a navigator and seaman was displayed when the party arrived at Tahiti several months before the predicted Transit of Venus. This allowed plenty of time to establish a semi-permanent settlement that became known as Fort Venus, with proper facilities for astronomer Charles Green to set up his instruments for observing the Transit.

The observations were reasonably successful, although there was some discrepancy in the times noted by the several observers, which affected the accuracy of the calculations. Taking advantage of the location, Green continued making astronomical observations for another two months. Some of Cook's notes on his own observations are held at Mitchell Library in Sydney. Although Charles Green died on the voyage home, full reports of Green's and Cook's observations were published by the Royal Society in London, the sponsors of the expedition.



Observatory tent as used by Cook's party at Fort Venus, Tahiti. A similar tent was used by the La Pérouse expedition in Botany Bay. The wooden framework was covered with canvas, leaving an aperture for the telescope. (Alexander Turnbull Library, Wellington, New Zealand, B-091-008)

While Charles Green was observing various celestial bodies, the 26 years-old Joseph Banks used his time at Tahiti to gather botanical specimens, and to make ethnological studies of other bodies, remarking on the 'infinite smoothness' of the women's skin, and commenting that 'these people are free from all smells of mortality and surely ... it must be preferred to the odoriferous perfume of toes and armpits so frequent in Europe.' (Engledow 2008). Because there was no need for their nautical skills on shore, most of Cook's crew devoted their time to similar pursuits by giving a different interpretation to the 'transit of Venus'.

After completing the observations in Tahiti, Cook set off on the secret part of his mission – to discover if a great south land existed to balance the northern hemisphere land masses, as many geographers inferred. The British government hoped that this was correct, imagining untold wealth like the Spanish had discovered in the Americas. Cook soon concluded there was no *Terra Australia Incognita*, but as part of his voyage of global circumnavigation he charted the entire coast of New Zealand, and then the eastern coast of New Holland, for which he claimed possession by the British Crown as New South Wales. We know from Cook's journal that Charles Green began taking celestial measurements on 30$^{\text{th}}$ April 1770, the day after they arrived in Botany Bay. Thus Green became the first professional astronomer to practice on Australian territory.

After returning to England, Joseph Banks went on to become President of the Royal Society, the dominant figure in English science, serving in that office for an unequalled 42 years until his death in 1820. When asked to suggest a site for the transportation of England's surplus criminals, Banks proposed Botany Bay, where he had collected many new species of plant and animals years earlier. That advice was followed and as we know, the First Fleet arrived there at the beginning of 1788.

However, after spending just a week in Botany Bay, Captain Arthur Phillip decided to take his eleven ships to the more congenial environment of Sydney Cove. By remarkable coincidence, the French Comte Jean-François de Galaup La Pérouse sailed into Botany Bay as Phillip was leaving, and set up an encampment on the northern shore, at a location now known as Frenchman's Beach. Following bad experiences at other places he had visited in the Pacific, La Pérouse built a solid palisade around the camp site to protect men and materials from pilfering or attack – rather similar to Fort Venus erected by Cook on Tahiti 19 years earlier.

Amongst the French party was Joseph Lepaute Dagelet (1751–1788), a capable astronomer, who immediately set up a tent to house his instruments and form an improvised observatory. Aged 37 when he arrived in Botany Bay, Dagelet was the youngest Associate Member of the French Academy of Sciences. At first reluctant to join the expedition, it was only following entreaties from the Minister that he agreed to take part. A sensitive soul, he did not enjoy the rough company of sailors, who he wrote to a friend 'sing, swear, smoke, drink and speak of girls all in the same half an hour', although he got on well with La Pérouse. Officers of both the French and English navies visited each other from their respective camps in Sydney Cove and Botany Bay, although Arthur Phillip and La Pérouse never met personally (Barko 2007). The French Revolution began with the fall of the Bastille the following year.

While Dagelet was setting up his observatory at Frenchman's Beach, about 15 kilometres to the north Second Lieutenant William Dawes (1762–1836) of the British Marines was unpacking the telescopes and astronomical instruments supplied by the Board of Longitude in order to observe the expected appearance of a comet later that year (it did not appear). He named his chosen site Point Maskelyne, after his mentor and patron Dr Maskelyne, the Astronomer Royal. This is the location which we now know as Dawes Point. We have some idea of what his observatory looked like from a written description and a sketch he made in a letter home; a convincing re-creation of this building was built in the now-defunct Old Sydney Town theme park near Gosford.

A week after their arrival, Dawes accompanied Lieutenant Philip Gidley King on a visit to the French fleet. The two astronomers met and

exchanged information about their work. Later, Dagelet wanted to visit Dawes by trekking overland, but La Pérouse would not permit this because of unknown dangers. However, one of the French officers did visit Dawes at his observatory site, and reported back to Dagelet, who wrote a long letter to his English counterpart which is now in the Mitchell Library.

Dagelet and La Pérouse never returned to France because their expedition was wrecked in the Solomon Islands and their fate is unknown. Underwater archaeological exploration at the site has yielded a number of scientific instruments of the period, probably including those used by Dagelet. All the records of his observations sank with the ships, with the exception of that letter to William Dawes written on 3 March 1788 in which he gives the geographical co-ordinates of the Botany Bay observatory and some other technical advice to his less-experienced British counterpart.

William Dawes used this information when he established accurate geographical coordinates for Sydney, but he also had other responsibilities in the new colony, which needed his training as an engineer and surveyor to lay out streets and fortifications. He hoped to remain in NSW if a suitable position could be found for him, but after a couple of clashes with Governor Phillip, he was obliged to return to England with the marine contingent in 1791, taking his borrowed instruments with him. With no other trained astronomer in the colony, and no instruments, the wooden observatory building soon fell into disrepair (Mander-Jones 1966). Dawes has been treated kindly by historians and novelists because of his apparent benevolence towards the Aborigines[3] but recent research has painted an entirely different picture of the man in his subsequent career as governor of Sierra Leone, where he allegedly engaged in slave-trading amongst other crimes (Pybus 2009).

Towards the end of Lachlan Macquarie's term as Governor in 1821, a small group of educated men in the colony formed the Philosophical Society of Australasia, which became the forerunner of the present Royal Society of New South Wales as well as the indirect antecedent of many other Australian scientific organisations and learned societies. While the early years had been devoted to eking out a tenuous subsistence in a strange environment, by this time increased prosperity gave a little scope for more leisurely pursuits. Nevertheless, Charles Darwin remarked somewhat tartly when he visited Sydney in 1836 that the main topic of conversation was sheep and wool. Darwin was not an astronomer, but HMS *Beagle* did carry 22 chronometers to verify their accuracy over a long period under arduous conditions. Although the Board of Longitude had been disbanded in 1828, there were still some lingering doubts about the reliability of the new technology.

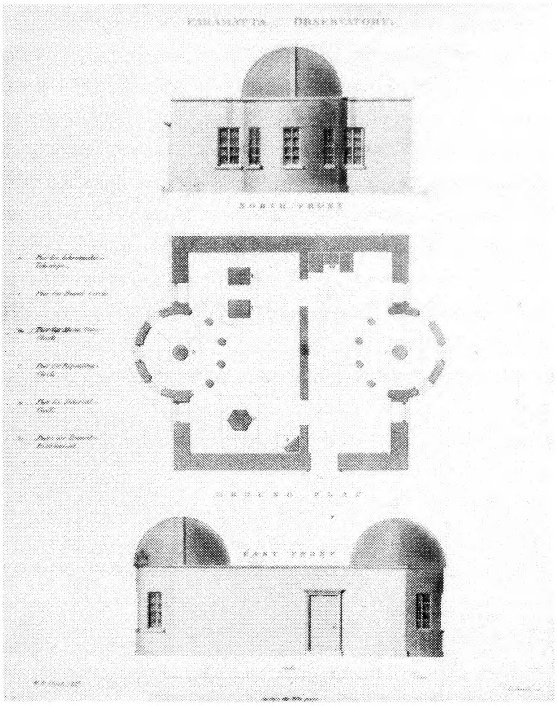
At the end of 1821 a new Governor, Major-General Sir Thomas Brisbane (1773–1860) arrived in the colony together with his family, a retinue of servants, a personal physician, a French chef, and two scientists. Because the Macquaries were still living in the original Government House in Bridge Street, Sir Thomas and his entourage settled into the other (and larger) official residence at Parramatta. Lady Brisbane was sickly, and both she and her husband preferred the climate and unpolluted atmosphere of Parramatta, so the Governor remained there throughout his tenure, only visiting the city establishment one day a week to transact his official responsibilities. This caused considerable resentment amongst the senior administrative, legal and military officers who had to travel to Parramatta to transact their business.

Like Macquarie, Brisbane was a military man and a Scotsman. Living on half-pay since the defeat of Napoleon and only recently married, he sought the appointment to New South Wales in order to maintain his lifestyle (Liston 1996). He had been elected a Fellow of the Royal Society in London because of his interest in astronomy, and he was excited by the possibility of exploring the skies of the southern hemisphere. He brought with him

[3] See for instance G. Karskens, The Colony, 2009; I. Clendinnen, Dancing With Strangers, 2005; T. Flannery, The Birth of Sydney, 1999, and for a novel based on Dawes, see Kate Grenville, The Lieutenant, 2008.

the latest instruments and two astronomical assistants, Carl Rümker and James Dunlop. Under the Governor's supervision an elaborate observatory building was erected in the grounds of Government House at his own expense, and a rigorous program of celestial observations commenced. During the daytime, Brisbane occupied himself with that favourite pastime of the landed gentry to which he belonged – hunting – leading to the accusation that he spent his nights looking at stars and his days chasing parrots (Liston 1985).

During 2009 the Parramatta Park Trust has been conducting an archaeological dig at the site of Brisbane's observatory, and has unearthed some new evidence that still awaits interpretation.



Plans for Sir Thomas Brisbane's observatory at Government House, Parramatta. Governor Brisbane, a notable astronomer, was President of the Philosophical Society of Australasia 1821–2. He later became President of the Royal Society of Edinburgh. Only a few remnants of the Parramatta observatory that he built now exist. (Mitchell Library, State Library of NSW, GPO1-23235)

After four years in Sydney, Sir Thomas Brisbane was recalled to Britain and returned to his estates in Scotland, where he built an observatory to continue his astronomical observations. As a result of this work he was elected President of the Royal Society of Edinburgh, with numerous publications to his credit.

Christian Carl Ludwig Rümker (1788–1862) was born and educated in Germany, but at the age of 21 went to England and served a period in the Royal Navy, where he became interested in astronomy before returning to Hamburg as a teacher of navigation. Governor Brisbane paid him a salary of £200 a year to become his private astronomer. Soon after the Parramatta observatory opened it came to international attention when the trio of astronomers observed the return of Encke's comet, which became only the second comet to have its return successfully predicted in advance, the first being Halley's Comet (Pickett & Lomb 2000, p. 25).

The grateful governor granted Rümker 1,000 acres of land at Picton as a reward. Twelve months later he deserted his job at the observatory and moved to his new rural property. Brisbane was furious, and tried to revoke the land grant. Relations between the two men collapsed (Bergman 1960).

After Brisbane returned to England, the government acquired his observatory. Rümker then resumed astronomical work at Parramatta in May 1826, and discovered another comet. The new governor, Ralph Darling appointed him to the position of Government Astronomer, the first person to hold this title. However, when he went to London in 1829 to purchase new instruments, Sir Thomas Brisbane used his influence to have Rümker dismissed from government service. For many years afterwards Brisbane and Rümker maintained a vitriolic correspondence. Rümker returned again to his native Hamburg and became director of the observatory there, while continuing to work on his Australian star catalogue. He received many international awards for his achievements, but is little recognised in this country (Bergman 1967).

James Dunlop (1793–1848) was born in Scotland of humble parents. With little formal education he showed great aptitude for mechanical craftsmanship, making his first telescope at the age of 17. Sir Thomas Brisbane selected him as one of his two astronomical assistants because of his facility with instruments, whereas Rümker was primarily a mathematician. Dunlop made about 40,000 observations at Parramatta in the four years after Rümker left suddenly, although the quality is rather poor because of inaccurate instruments. In 1831, James Dunlop was appointed superintendent of the observatory. After 1837, however, his activity declined, perhaps due to poor health. Much of his work in this period was never published, and he resigned in 1847, dying the following year (Wood 2009).

In contrast to the volatile Carl Rümker, James Dunlop had an outgoing, friendly personality, with a wide range of interests outside astronomy. Dunlop Memorial Park at Kincumber, near Gosford, where he lived commemorates his work. A memorial tablet in the local Church of England describes him as 'Astronomer Royal at the Observatory Parramatta', which overstates the position he held as superintendent. Although both Rümker and Dunlop (and Brisbane) were awarded the Gold Medal of the Royal Astronomical Society in London, Dunlop was never accepted into the educated ranks of class-conscious Sydney and was not invited to join the Philosophical Society.

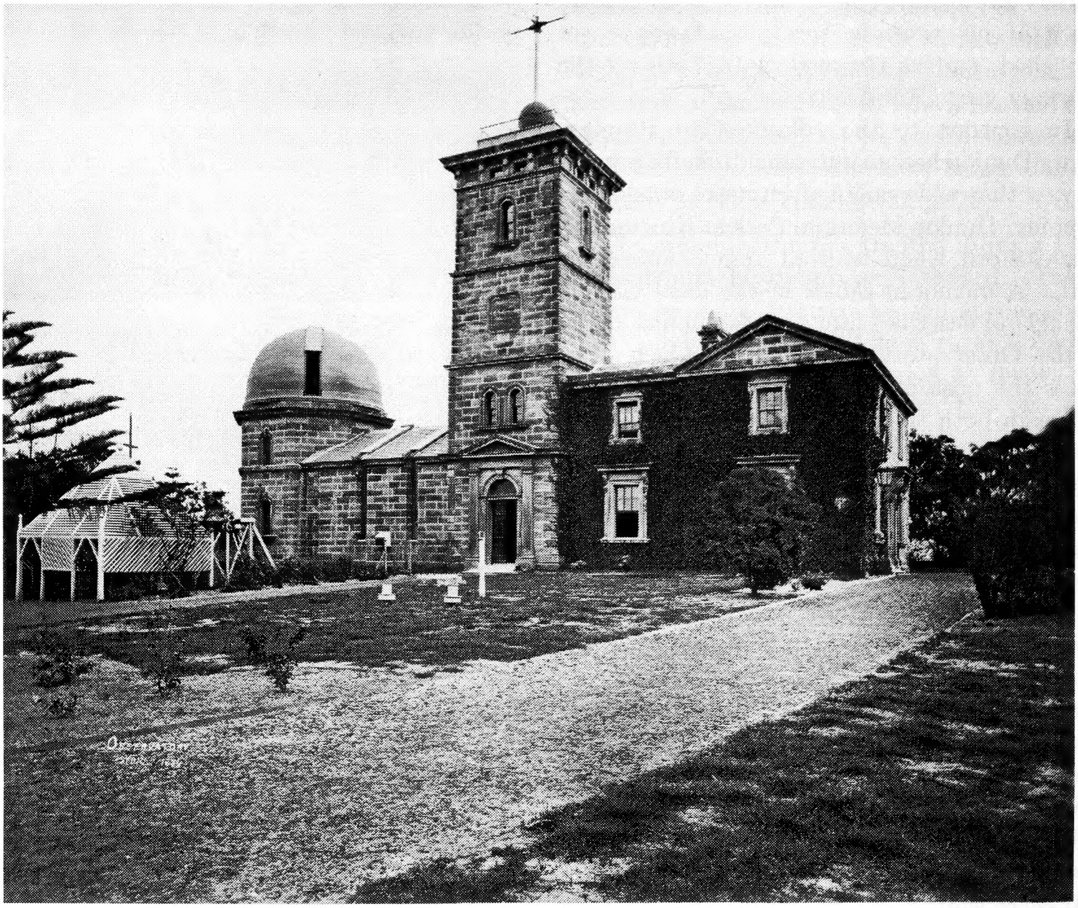
Rev. William Scott (1825–1917) became the first director of Sydney Observatory, although his biographer incorrectly called him the first Government Astronomer. While a mathematics lecturer at Cambridge University, he was selected by then Astronomer Royal, Professor George Airy, for the position in Sydney. He arrived in 1856 – the year that the colony achieved responsible self-government, and the year after the railway to Parramatta opened – and was able to help with planning the observatory building which opened in 1858. However, when he returned to Sydney from travels around the colony to set up meteorological stations, he found that the central tower had been built taller than he expected, in order that the time ball could be clearly visible to ships in all parts of the harbour. This meant that the critical eastern horizon could no longer be seen from the telescope dome. That decision revealed the government's true priorities; to provide accurate timekeeping for navigation. The northern dome with unimpeded view was only built after Scott's departure. Initially he had to work with the old instruments from Parramatta, although he persuaded the government to order a large telescope from Germany. He was criticised in the press when amateur astronomer John Tebbutt at Windsor discovered a new comet before Scott observed it, but after all that was not his mandate. Somewhat discouraged, William Scott resigned in 1862 to return to his earlier vocation of teaching (Doyle 2008).

Rev. William Scott, Government Astronomer and first Director of the Sydney Observatory, 1856–1862. He helped with planning the new building, but his scientific work was hampered because initially he had to use the outdated instruments from Governor Brisbane's observatory at Parramatta. (Mitchell Library, State Library of NSW, GPO1-13544)

George Robarts Smalley (1822–1870) succeeded Scott. The son of a Church of England clergyman, he became an astronomical assistant at the Royal Observatory in Cape Town after completing his degree at Cambridge. Later he became a mathematics professor, before the Astronomer Royal recommended him for appointment as the government astronomer in Sydney. His interests were in meteorology and trigonometric surveying rather than celestial astronomy, and these coincided with the government's pragmatic instincts. He organised automatic recording of harbour tides at Fort Denison, and expanded the network of volunteer weather observers throughout the colony[4] (Wood 1976).

George Smalley was unusual for a mid-nineteenth century scholar in wishing to see a greater female involvement in the sciences, albeit expressed with a paternalistic Victorian overtone: '*a knowledge of science in ladies is not inconsistent with their natural refinement, or incompatible with their usefulness in domestic and social life*' (Smalley 1868).

Sadly, Smalley died suddenly two years after this address to the Royal Society of NSW in 1868, so was unable to put his ideas into effect. It was to be another seventy years before women were allowed to join the Royal Society.



Sydney Observatory in 1874. Opened in 1858, the building and its surrounds look almost identical today, although it is now an adjunct of the Powerhouse Museum. The tower housing the time-ball obscured astronomical observations from the adjacent dome. (Mitchell Library, State Library of NSW, a089304)

[4] H.C. Russell later pointed out that the tide readings were inaccurate, because they were measured with a hempen rope whose length varied with atmospheric conditions.

Henry Chamberlain Russell (1836–1907) has been called one of the most eminent men of Australian science in the nineteenth century. Born at Maitland, after graduating from Sydney University he joined the staff of the Observatory as a 'computer', and became the first Australian-born Government Astronomer when George Smalley died in 1870, holding the position for the next thirty-four years. During this time he discovered 500 new double stars, and published over 130 papers. For the 1874 Transit of Venus, he set up temporary observatories in several locations in NSW in order to minimise the possibility of clouds obscuring the event, which he described as 'very remarkable and beautiful'.

Henry Chamberlain Russell, NSW Government Astronomer 1870–1907. He was a skilled photographer and inventor. Four times President of the Royal Society of New South Wales. The first graduate of University of Sydney to be elected a Fellow of the Royal Society, London. (Mitchell Library, State Library of NSW, SPF/P1/Russell)

In addition to pure astronomy, Russell was keenly interested in photography and meteorology, inventing new recording instruments and re-establishing the weather stations discontinued by his predecessor, so that he could issue a daily weather map to the newspapers. By 1898, he had 1600 observers throughout the colony of New South Wales sending data by telegraph. He was the first graduate of the University of Sydney to be elected as a Fellow of the Royal Society of London, and he was president of the Royal Society of NSW four times. He later became Vice-Chancellor of the University.

Henry Russell believed that the scientist must be 'patient in investigation, accurate in measurement, cautious in accepting results.' A vigorous, uncompromising man, he made his share of enemies. In 1877 there was an assassination attempt when a bomb was delivered to him at the Observatory; two of his staff were charged, but acquitted because the evidence was circumstantial. Then in 1889 he was physically attacked by one of his workmen (Walsh 1976). He retired in 1905, dying in 1907 while still living at the Observatory.

Henry Alfred Lenehan (1843–1908) had a variety of jobs before being appointed as assistant to H.C. Russell in 1870, cataloguing accurate star positions for the next 37 years. Lenehan was appointed Government Astronomer in 1907, and made a number of significant changes in the work of the Sydney Observatory. He began taking measurements of the force of gravity, and used the branch observatory at Red Hill near Pennant Hills to investigate magnetic fields. This was no longer possible in the city because of interference caused by the electric trams. Like his predecessors and most of his successors, Lenehan was an active member of the Royal Society of New South Wales (Wood 1986).

When Henry Lenehan died, there was a hiatus of four years before William Ernest Cooke (1863–1947) was appointed Government Astronomer in 1912, holding this position jointly with that of Professor of Astronomy at the University of Sydney. Observations continued under his leadership, but in 1926 he took early retirement when the Government decided

to curtail the activities of the Observatory (Hutchison 1981).

While Lenehan was working as astronomical assistant to Henry Russell, Henry Ambrose Hunt (1866–1946) became the meteorological assistant at Sydney Observatory in 1890, responsible for preparing the daily weather map, and working with Russell investigating the movement of anti-cyclones. After Federation, he went to Melbourne in 1906 as head of the new Commonwealth Meteorological Bureau (Walsh 1983).

Then, as now, some people were sceptical about the validity of weather forecasting. Pietro Baracchi, the government astronomer in Victoria in the 1890s, remarked that what he termed 'popular meteorology' was 'of little practical value except as an amusement, and of doubtful credit to science.' (Perdix 1979). To him it was on a plane with astrological horoscopes.

William Shakespeare was making an identical point around the same time Galileo was making his observations: '*Why didst thou promise such a beauteous day, And make me travel forth without my cloak, To let base clouds o'ertake me in my way ...*' (Shakespeare[5]) Shakespeare may have been speaking metaphorically, but the point is still valid.

Professional scientists were rare in the nineteenth-century, therefore it is not surprising to find that serious astronomical investigations were being made by men who were not paid Colonial officials. One of the most significant of all Australian astronomers was John Tebbutt (1834–1916) at Windsor, whose observatory still exists. Tebbutt was offered the position of Government Astronomer when William Scott resigned, but he didn't relish the 'blighting influence' of the civil service and preferred to maintain his independence as a researcher. Educated locally – he never left Australia – his family were relatively prosperous farmers. He had bought his first instrument, a marine sextant, at the age of nine, and continued to acquire mechanical and optical objects throughout his life.

Tebbutt built an international reputation for his accurate observations of comets and minor planets, and his publications were in much demand. He was regarded as Australia's leading astronomer in the late nineteenth century (Orchiston 1989). Tebbutt discovered the great comet of 1861, which is one of the finest comets on record, and discovered another major comet in 1881. He observed the return of Encke's comet on seven occasions (Wood 1976).

Closer to the city there is the observatory in the grounds of St. Ignatius' College, Riverview. This began in 1908 under the direction of Father Edward Francis Pigot (1858–1929). Born in Ireland, he initially studied medicine and set up practice as a doctor in Dublin. In 1885 he enrolled for the priesthood with the Jesuit order, first coming to Riverview in 1889. For the next 15 years he travelled extensively, including a period working at the famous observatory in Shanghai, before returning to Sydney in 1907. He immediately set about planning an observatory of international standard at the College. This included facilities for official daily meteorological observations, a function which continues today. Pigot was particularly interested in movements of the earth's crust, and established a fully-equipped seismological station. The only other equivalent station in the southern hemisphere was operated by the Swedish Academy of Sciences at Samoa, despite the fact that the south-west Pacific region is an area prone to earthquakes. Later he began studying variable stars and solar radiation, which he believed could be used in long-range weather forecasting.

Amongst his many other attributes, Father Pigot was an accomplished pianist, whose playing was once commended by Franz Liszt. As the distinguished geologist Sir Edgeworth David remarked, 'Surely there never was any scientific man so well-beloved as he (Drake 1988).

Some men who are remembered today for other achievements also made notable contributions to astronomical science, a discipline in which they were more than mere hobbyists.

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[5] Shakespeare, W. Sonnet 34.

Admiral Phillip Parker King (1791–1856) was born on Norfolk Island, the son of the third Governor of NSW, Phillip Gidley King, who had been the companion of William Dawes when they visited the La Pérouse expedition in Botany Bay. Phillip Parker King was a notable hydrographer as well as a keen astronomer, who built a private observatory on his property at Dunheved. King was influential in persuading the government to establish an observatory in Sydney, and he ensured that the instruments from Brisbane's Parramatta observatory remained in the colony as a nucleus for the new institution (Pickett & Lomb 2000, p. 22).

Phillip Parker King (1793–1856), foundation member of the Philosophical Society of Australasia, hydrographer, pastoralist and amateur astronomer. He was influential in having Sydney Observatory built. King was the son of the third Governor of NSW, and became the first Australian-born Admiral in the Royal Navy. (Mitchell Library, State Library of NSW, GPO1-17497)

Conrad Martens (1801–1878) is known primarily as one of the most distinguished early colonial artists. He was part of the research complement of HMS Beagle, during which he formed a lasting friendship with Charles Darwin. Martens left the expedition in Valparaiso, and made his own way to Sydney where he remained for the rest of his life (Dundas 1967). When he became a neighbour of Rev. W.B. Clarke, rector of St. Thomas's church in North Sydney, his latent interest in astronomy was fostered. Clarke has been called the 'father of Australian geology', but his interests extended to all the natural sciences, and he was a leading figure in the Royal Society of New South Wales. Conrad Martens acquired an astronomical telescope from London so that he and Clarke could observe the solar eclipse of 1856. His observational records demonstrate that this interest was a serious occupation (Ellis 1994). He, too, was an elected member of the Royal Society.

Philip Adams (1828–1901) became Surveyor-General, as well as a successful winegrower. He was responsible for the dome on the top of the Lands Department building in Bridge Street that was originally designed for astronomical observations by budding surveyors. Adams' reputation as an astronomer was confirmed by his selection as one of the official observers of the transit of Venus in 1874 at Woodford, and in 1882 at Lord Howe Island (McIntyre 1969).

Another member of the surveying staff, Joseph Brooks (1847–1918), carried out most of the original trigonometrical survey of NSW, working from a baseline at Lake George that had been started by Smalley (Nangle 1930). In order to ensure that titles to land ownership were accurately defined, it was essential that the location and length of this baseline were known precisely; this was achieved through astronomical observations. After his retirement Brooks furthered his lifelong interest in astronomy, taking part in a number of expeditions to observe total solar eclipses in the South Pacific region.

Lawrence Hargrave (1850–1915) is remembered as one of the pioneers of aviation. His experiments with box kites at Stanwell Park proved that heavier-than-air flight is feasible for humans. Hargrave made many experimental engines to power his kites, but could not develop a design that provided the required combination of power and light weight. Hargrave published his theoretical work on aerofoil wing design in the *Journal and Proceedings of the Royal Society of New South Wales.* He refused to patent any of his inventions, believing that

scientific knowledge should be for the benefit of all humankind. After receiving a comfortable inheritance, Lawrence Hargrave was able to pursue his scientific interests in many directions at once. Astronomy was one of his obsessions – perhaps linked to his desire to conquer the skies – and he had been engaged as an assistant astronomer at the observatory for five years from 1878 (Bhathal & Sansom 1988).

A man with a very different professional career was Walter Gale (1865–1945), who rose to become manager at the head office of the State Government Savings Bank. At the age of 19 he built his first 18 cm mirror telescope. Particularly interested in the surface of planets, he was the first person to note some of the topographical features of Mars, which he was convinced supported some form of life. He died in 1945 at the age of 80 while making his nightly telescopic sweep of the sky (Wood 1981).

James Nangle (1868–1941) a multi-talented architect who became Superintendent of Technical Education was a passionate astronomer. He designed an observatory for his Marrickville home, and built the telescopes he used there. Several of his papers and books on astronomy were published, gaining a reputation that resulted in him joining the official expeditions to view eclipses of the sun in 1910 and 1923. He helped re-design the Sydney Observatory and moved his family there after he was appointed honorary government astronomer in 1926 (Cobb 1986).

Sydney-born Thomas Roseby (1844–1918) had a brilliant career in Arts and Law at Sydney University, later becoming an ordained minister of the Congregational church, and a leader of the temperance movement both in New South Wales and New Zealand, where he spent 16 years. In 1888 he became minister at the Marrickville Congregational Church – later known as the Roseby Memorial Church – where he set up an observatory in order to pursue his interests in astronomy. He contributed papers to respected scientific journals, and arranged educational evenings for students at his home observatory, which he later moved to Mosman.

It is notable that a number of these men were clergymen, and from different Christian denominations – Maskelyne, Scott, Clarke, Pigot, Roseby, have been mentioned. By the nineteenth century most Christians accepted the proposition that the Earth revolved around the Sun, although they might still consider that humans were a unique, unchanging species in the universe. These beliefs were further challenged 150 years ago when Charles Darwin published his *Origin of Species*. Unlike many churchmen of his period, Thomas Roseby at Marrickville saw no inherent conflict between religion and science; he held that Darwin's evolutionary theory was not inconsistent with Christian belief, but 'simply a question of Divine method.' (Phillips 1976).

Of course, one reason for the involvement of so many clergymen in studying the natural sciences – including astronomy – during the nineteenth century, is that they tended to be better and more broadly educated than many of their contemporaries, few of whom had progressed beyond an elementary schooling.

Understandably, much of the effort of the early astronomers in Sydney was devoted to the practical needs of a new colony situated at the opposite end of the Empire. Consistent timekeeping, accurate fixing of positions both for navigation and land subdivision, understanding the weather patterns for agricultural purposes or tidal variations for fishermen, were all essential tasks. But this did not preclude plenty of pure scientific discovery as well. A comprehensive star atlas was begun as part of an international project, double stars were identified and measured, magnetic and geodetic surveys were carried out, and notable pioneering work in seismology all contributed to our understanding of natural phenomena.

As we moved deeper into the twentieth century, astrophysics rather than positional astronomy became the focus of most research. After the Second World War, Sydney-based scientific institutions became leaders in the field of radio astronomy, with many significant achievements to their credit. A number of notable physicists and astronomers contributed to these advances, but their careers lie outside the scope of this paper.

In any case, by mid-century optical astronomy had become impractical in Sydney, mainly due to increasing atmospheric pollution, and the brightly illuminated buildings that rendered the night sky all but invisible. Professional astronomers moved to remote rural locations such as Siding Springs near Coonabarabran, leaving enthusiastic amateur astronomical societies as the only regular users of traditional telescopes in the metropolitan area. Sydney Observatory closed for scientific observations in 1982, and has now become an adjunct of the Powerhouse Museum, with informative displays both of historical and contemporary astronomy, so that the achievements of the pioneers have not faded from view like the objects they once observed from that site.

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Pre-contact Astronomy

RAGBIR BHATHAL

Abstract: This paper examines a representative selection of the Aboriginal bark paintings featuring astronomical themes or motives that were collected in 1948 during the American-Australian Scientific Expedition to Arnhem Land in north Australia. These paintings were studied in an effort to obtain an insight into the pre-contact social-cultural astronomy of the Aboriginal people of Australia who have lived on the Australian continent for over 40 000 years.

Keywords: American-Australian scientific expedition to Arnhem Land, Aboriginal astronomy, Aboriginal art, celestial objects.

INTRODUCTION

About 60 years ago, in 1948 an epic journey was undertaken by members of the American-Australian Scientific Expedition (AAS Expedition) to Arnhem Land in north Australia to study Aboriginal society before it disappeared under the onslaught of modern technology and the culture of an invading European civilisation. It was believed at that time that the Aborigines were a dying race and it was important to save and record the tangible evidence of their culture and society. The leader of the scientific expedition referred to Arnhem Land as still being in the Stone Age (Mountford 1949). It was seen as the last frontier. The philosophy that guided the collections of the material culture of the Aboriginal people of Arnhem Land was based on Social Darwinist views which were prevalent in the 19th and early twentieth centuries thinking among intellectuals from the metropolitan centres of learning. They held the view that there was an evolutionary ladder in the progress of human beings and cultures (Griffiths 1996). The Aborigines were considered to be on the bottom rung of this ladder.

The official aims of the expedition were to observe the every day life of the Aborigines of Arnhem Land, to determine where they originally came from, to learn how they coped with their environment and to obtain specimens of their material culture (Mountford 1949). The expedition was funded by the National Geographic Society, the Smithsonian Institution and the Commonwealth Government of Australia. One of the reasons for the Commonwealth Government supporting the expedition was that it was anxious to foster good relations between Australia and the US following World II and the other was to establish scientific cooperation between Australia and the US.

The Collection

The expedition was organised and led by Charles Mountford, a film maker and lecturer who worked for the Commonwealth Government of Australia and an Honarary Assistant in Ethonology at the South Australian Museum. The bulk of the bark paintings and ethnographic material were collected from the three base camps at Groote Eylandt, Yirrkala in north-east Arnhem Land and Oenpelli in western Arnhem Land. They also visited Milingimbi Island, Chasm Island and Winchelsa Island but for shorter periods. The expedition lasted from May to early November 1948. Mountford's collection strategy was to set up a 'shop' in a big tent and ask the local people to bring goods which they wanted to trade. It is not known what he paid them but he obtained interpretations of the items the people brought to him.

In the case of the bark paintings, Mountford (1956) asked the Aboriginal people to make paintings for him. He says that he seldom suggested a subject. At the end of the day, the artists brought their work to his tent, related the associated myth, and explained the meanings of the designs. However, in the case of the astronomical paintings, Mountford suggested the subjects to be painted.

Thus, the astronomical folklore was collected within the perspective of the European astronomical knowledge system and his limited knowledge of astronomy. In fact, in his book "Brown Men and Red Sand" (Mountford 1949), wrote that although in the early days among the Aborigines he could recognise Orion, Scorpio and the Southern Cross, he found that the other constellations such as Argo, Delphinus, Hercules and others were beyond him. His knowledge of the sky was backed with little information. This is one of the reasons why the information collected on the astronomy of the Aborigines in Arnhem Land is rather limited and confined to those celestial objects and parts of the sky that Mountford was familiar with. Only three examples are provided by him of the actual Aboriginal constellations. However, the information on these is not complete and the stars are not indentified by Mountford. Furthermore, the provenance of the paintings leaves much to be desired. Whilst the locations where the paintings were collected from is provided, however the information on the artists who painted the astronomical paintings is incomplete. Mountford notes that when the supply of prepared sheets of bark at Yirrkalla and Oenpelli became exhausted, he provided the artists with sheets of rough-surfaced grey and green paper (Mountford 1956). This explains why some of the paintings are on paper.

The interpretations that Mountford recorded were very basic. Since the artists had to explain their paintings in broken English it may be the case that the recorded interpretations may be incomplete. He does not tell us whether he checked the paintings with the positions of the celestial bodies in the night sky. He informs us that in the late afternoon, when the Aboriginal artists had finished their work, he would sit among them listening to stories they had illustrated on sheets of bark. Despite these short comings we have a valuable collection of pre-contact stories of the night sky which are illustrated by paintings. It is probably the single largest collection of astronomical paintings from an ancient culture.

The pigments used to paint the designs of the bark paintings were red, yellow, black and white. On Groote Eylandt the black came from the carbon of dry batteries discarded by the Air Force after the war. The paintings have a mixture of the early style of cross-hatching, broken lines, parallel lines, circles and circles with radiating lines. The artists used three kinds of brushes, viz: a narrow strip of bark, chewed at one end for making broad lines, a thin cylindrical stick with the ends slightly burred for making dots and a brush made from a few fibres of palm leaf to make fine lines.

The expedition was a great success. In addition to collecting 13 500 plant specimens, 30 000 fish, 850 birds, 460 animals, the collection also included 2 144 ethnographic artefacts, including 484 bark paintings (Mountford 1956). For the purpose of this study it is rather unfortunate that at the end of the expedition the collection of bark paintings was dispersed to various institutions in Australia and the Smithsonian Institution in Washington in the US. Thirty six of the bark paintings in the collection were on the astronomy of the Aboriginal people. These were also dispersed and as a consequence of this it has been an extremely difficult task to locate them in the various institutions. The astronomical paintings have a collective story to tell. Unfortunately this was not considered important by the officials who sanctioned the distribution of these works of art and in particular those on the astronomy of the Aboriginal people. This may have been due to the fact that the officials lacked knowledge of astronomy. This paper is concerned only with the astronomical paintings.

Aboriginal Astronomy

In the 19th and early twentieth centuries a number of writers (Stanbridge 1861, Smyth 1878, Ridley 1875, Matthews 1905 and Maegarith 1932) had collected information on the astronomical stories and beliefs of the Aboriginal people. One of the significant things that emerges from these accounts is that astronomical knowledge was one of the principal branches of education among Aboriginal people (Dawson 1881). Another remarkable aspect of their astronomy is that long before other civilisations had named the celestial objects the Aborigines had given them names. For example, in Groote

Eylandt, the Milky Way was known as Ataluma, the Coal Sack as Alakitja, Venus as Barnimbida, the Moon as Jumuria and the star Achenar as Anguoa. In other localities the celestial objects were known by different names. The astronomy of the Aboriginal people was based on oral accounts that had been passed down from one generation to another over the 40 000 years that they have lived on the Australian continent.

In the 1940s when the AAS Expedition took place the Aborigines in north Australia were still enjoying the last vestiges of pre-contact culture and society. Most of their cultural heritage was intact although there were already inroads in spoiling their culture by Christian missionaries. Thus, the bark paintings that were collected provide us with the only examples of the astronomical knowledge system of the Aboriginal people in visual form. Thus, this collection of 36 paintings is unique in that it not only provides us with a visual representation but is also supplemented with an oral testimony of their meaning.

The subject of the paintings can be classified into the following categories for ease of discussion:

- Sun and Moon
- Planets: Venus and Jupiter
- Constellations and clusters: Southern Cross, Scorpio, Orion and the Pleiades
- Galaxies: Magellanic Clouds and the Milky Way
- Aboriginal constellations: Scorpion, the Crab and the Crocodile, the Oppossum and Ibis-men.

The above list is not exhaustive of what can be seen in the night sky at any one time with the naked eye. They represent what was of interest to the Aborigines in terms of their social cultural astronomy and the information that was collected by the collector. While there are some resemblances between the myths of Millingimbi and Yirrkala which are in relative close proximity, those from Oenpelli, Groote Eylandt and Yirrkala show differences. This may be the result of the larger distances between these places and a lack of sustained interaction between these communities.

The paintings are not just plain representations of the celestial objects that one sees in the night sky. They are much more complex and symbolic and thus they have to be interpreted by the artists since they have meanings encoded in them. Unfortunately, Mountford does not provide us with a full context for all the paintings and the social cultural aspects of the astronomy of the Aboriginal people.

Sun and Moon

The Sun and Moon are the most conspicuous celestial objects and hence play an important role in Aboriginal society and culture. Unlike other cultures the Sun in Aboriginal social cultural astronomy is seen as a woman. Hence, it is given a lower status than the Moon which is considered a male.

On Groote Eylandt the Sun-woman (Mamoura) is associated with the female turtle, Imoraka which is seen to leave and enter the water again. This is illustrated by a song about the turtle. These acts of leaving and entering the water are used to explain the rising and setting of the Sun. At another level the bark painting does not just refer to the celestial objects and their movements but it represents ancestral celestial beings who are related to creation stories, such as the formation of the land or the islands and to places of significance. The Sun-woman and her husband are seen as ancestral people whose bodies when they died were transformed into two low rocks on the seashore. Thus, what is seen on the land is reflected in the sky and vice-versa - an important philosophical concept in Aboriginal society and culture. In Yirrkala, the Sun-woman, Walo rises from a far away place beyond the eastern horizon called Turinjina and disappears beneath the western horizon at a place called Biminura. She then changes herself into a wallaby and returns again in the east by hopping along an underground tunnel. This story explains the rising and setting of the Sun on a daily basis. In Milingimbi the Sun-woman transforms herself into a Warrukay fish in the evening and swims under the earth and reappears in the morning as the Sun (Isaacs 1980). Since they are fishing communities it is understandable that the imagery they use is associated with fishing activities.

The Moon is not only associated with death but also pregnancy. This belief is not only confined to the Aboriginal people of Arnhem Land but is also shared by other Aboriginal groups on the mainland. Young girls are told not to look at the Moon unless they want to become pregnant. In many stories in Aboriginal social-cultural astronomy the Moon is associated with death. While everything on earth is destined to die the Moon is reborn at the end of every month. In Yirrkalla the explanation for the resurrection of the Moon is explained thus. In a heated argument the parrot-fish (Dirima) and the Moon-man (Alinda) hit each other so badly with their clubs that they died. The spirit of the Moon-man told the spirit of the parrot-fish that he would go to the sky and become the Moon, while the parrot-fish and everything else on earth would die. The Moon-man, on the other hand would die for three days and be reborn. The pearly nautilus (*Nautilus pompilius*) is supposed to be the skeleton of the dead Moon. The Aborigines on Groote Eylandt and Yirrkalla have an explanation for the waxing and waning of the Moon. According to them we get a full Moon when the high tides run into the Moon and make it fat and round. When the tides are low, the water runs out of the Moon and we get a thin Moon.

In Milingimbi the Moon has a different origin. It is associated with the deceit and greed of two sons who having caught a whistling duck did not share it with their father. The angry father put them in a bag and took them out to sea and threw them overboard. In their anger his wives set fire to the hut he was sleeping in. He was carried away by the fire into the sky where he turned into the Moon. From his lofty position he decreed that every living thing would die except himself. He would die for three days a month and be born again. This explains the phases of the Moon according to the Aborigines at Milingimbi.

The status of these pre-scientific explanations of the phases of the Moon are not dissimilar to the pre-scientific explanations given by Aristotelian physics as to why objects fall to the ground or why projectiles are able to move through the air. According to Aristotelian physics an object falls to the ground because it's natural motion is towards the centre of the earth. Aristotelians explained the continued motion of a projectile or an arrow by saying that the air which was being pushed and compressed in front had to rush behind to prevent a vacuum from forming there. They reasoned that God hated a vacuum. It was criticisms of these pre-scientific ideas of the Aristotelians that eventually led to the rise of modern science (Butterfield 1957).

The Planets

The stars and the planets that were observed by the Aborigines were associated with family and kinship relationships based on their philosophy that what is practiced on the land is reflected in the heavens. Thus, on Groote Eylandt Venus and Jupiter have two children who are the stars Lambda and Upsilon in the sting in the constellation of Scorpio. In other parts of Australia the Aboriginal people also used the celestial bodies to represent family relationships and kinship ties. Kinship ties formed the basis of social structure in Aboriginal societies that regulated marriage and other activities. The Aranda and Luritja people at Hermannsburg in Central Australia saw the night sky as two great camps that were separated by a large river, the Milky Way. The stars to the east of the celestial river were known as Aranda camps and the stars to the west of the river were considered to be Luritja camps. This division provided them with a class system which regulated acceptable marriages (Maegraith 1932).

Mars, Saturn, Jupiter and Venus were observed by the Aborigines. Of these four planets, Venus plays a significant role in Aboriginal life. Venus is very conspicuous in the sky and the Aborigines know it as the Morning and Evening Star. To the Aborigines in northeastern Arnhem Land, Venus is known as the Morning Star or Barnumbir and is associated with death. Barnumbir is held on a long string by two old women on the Island of the Dead (known as Purelko in Yirrkalla, Djiraia in Milingimbi or Bralgu) to ensure that Barnumbir does not escape. In the painting (Figure 1) the morning star is imprisoned in a bag shown at the bottom

of the painting by the two women. Just before dawn Barnumbir is let out of the bag so that the star can wake up the Aborigines and give them messages from the dead. Each of the blossoms represents a locality he visits withe messages. At dawn the star is pulled back to the shore and kept in a bag during the day. The process is repeated again next morning. Since Barnumbir is tied by a string the star never rises very high in the sky and can thus be seen most clearly at dawn or dusk. The Aboriginal people in northeastern Arnhem Land perform morning star ceremonies to ensure that the deceased travels safely to the Land of the Dead. The ancestral beings made feathered strings that they attached to the Morning Star to guide the dead person's spirit or soul to his/her final resting place. In the performance of the ceremony the Aborigines use a large pole decorated with feathered strings and a ball or bunches of sea gull feathers. The ball represents the Morning Star. (Berndt, Berndt and Stanton 1998, Mountford 1956).

Constellations

The Southern Cross is the most famous constellation in the southern hemisphere. It was first observed by Andreas Corsali in 1572 on a voyage to Goa in India (Bhathal and Bhathal 2007). But the Aboriginal people have been observing it for over 40 000 years. It is called by various names and has a number of different stories attached to it. There is a wide difference in the interpretation of the Southern Cross and the Pointers between Yirrkala and Groote Eylandt. In Yirrkala it is seen as a sting ray being chased by a shark (Figure 2). The Cross is the sting ray while the shark represents the Pointers. On the other hand at Groote Eylandt the Southern Cross is seen in association with the Coal Sack and the Pointers. Alpha and Beta Crucis represent two brothers who have speared a large fish (the Coal Sack) and are cooking it on two fires represented by the other two stars of the Southern Cross (Delta and Gamma Crucis).

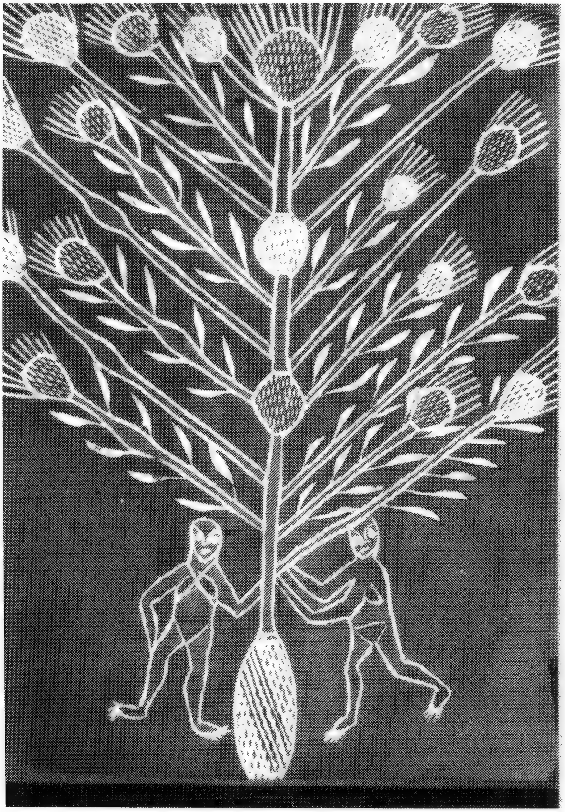

Figure 1. Venus – the Morning Star or Barnumbir.

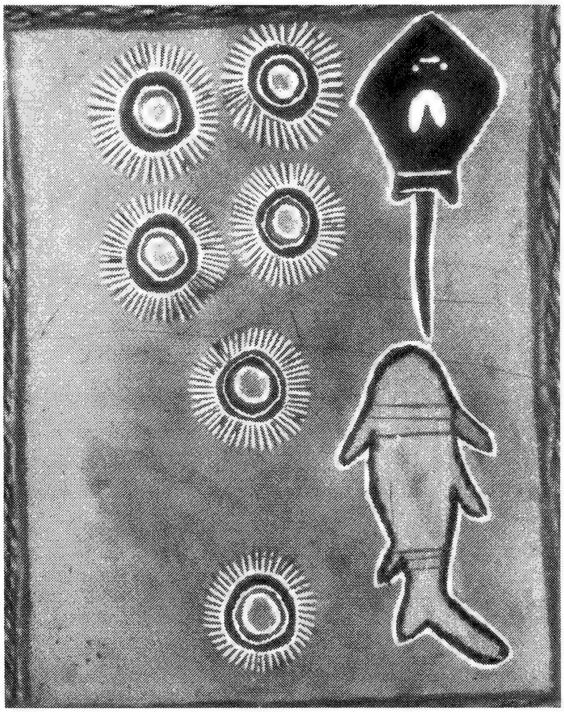

Figure 2. The Southern Cross.

In contrast the Aborigines in central Australia look upon the Southern Cross as the footprints of the wedge-tailed eagle. While the pointers (Alpha and Beta Centauri) are his throwing stick and the nearby Coal Sack (the dark patch) is his nest (Mountford 1976). On Stradbroke Island the Southern Cross is seen as Mirabooka, a kindly man who has been put in the sky by the Great Spirit, Biami to look after his people (Walker 1972).

It is rather interesting to note that in many cultures around the world the Pleiades are seen as the seven sisters or a group of girls (Andrews 2004). They are normally associated with the stars in the Orion which are seen as a group of men or a man. On Groote Eylandt, Yirrkala and Milingimbi, Orion and the Pleiades are represented as fishermen and their wives respectively who live in harmony. The representation of Orion and the Pleiades as fishermen and their wives is strongly linked to their style of living in a fishing community. The painting (Figure 3) shows a canoe which carries three fishermen (stars in Orion's belt) and their wives sitting at the other end (Pleiades). The paddles represent long lines of stars stretching to the north and south. The fish in the sea may be other stars in the Milky Way. It may be the case that the association of the Pleiades with women was transferred to the Aborigines in north Australia by the Macassan fishermen who used to visit north Australia on their fishing expeditions in search of trepang (also known as sea-slug or beche-de-mer). Trepang was prized by the Chinese community in South East Asia for its culinary as well as supposed aphrodisiac properties (Mulvaney and Kamminga 1999). The harmonious relationship which existed between Orion and the Pleiades in north Australia is not repeated in the stories of these celestial objects as seen by the Aborigines in Central Australia. Here the stories are of violence where the men in Orion are constantly chasing the seven sisters. It also needs to be pointed out that the stories about the Pleiades are classified as secret women's business in some parts of Australia and are only known to those who need to know them. The secrecy of these stories has had dire consequences for some Aboriginal groups, such as in the case of the Hindmarsh Island Bridge Affair where a bridge was built between the mainland and the island with absolute disregard for the tradition and culture of the Aboriginal women (Simons 2003).

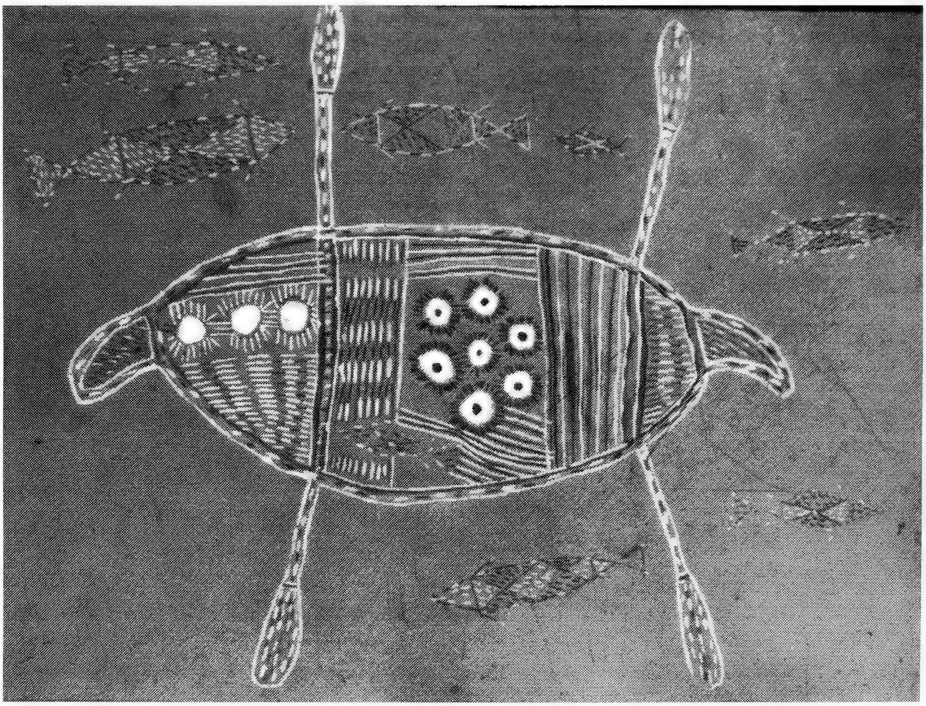

Figure 3. Orion (the three stars on the left) and the Pleiades (the seven stars on the right).

Galaxies

There are two galaxies of interest to the Aborigines. These are the Milky Way galaxy and the Magellanic Clouds. Far away from city lights, the Magellanic Clouds can be seen with the naked eye as two fuzzy patches of light in the night sky. On Groote Eylandt they are interpreted as the camps of an old man (Large Magellanic Cloud) and an old woman (Small Magellanic Cloud) who cook their food over a fire which is represented according to Mountford by the bright star Achernar (magnitude 0.43). The star is more likely to be Gamma Hydri (magnitude 3.25) in keeping with the significance of fainter stars in Aboriginal astronomy. [Brighter stars have numerically smaller magnitudes than fainter stars. Thus, a star of magnitude 0.43 is brighter than a star of magnitude 3.25. The magnitude is a measure of the brightness of a star.]. However, in Yirrkalla the Magellanic Clouds are given a different interpretation. They are interpreted as the homes of an older sister (lower figure), Nujai who lives with her dog in the Large Magellanic Cloud and a younger sister (upper figure), Narai who lives with her dog and children in the Small Magellanic Cloud (Figure 4). The interpretation of these celestial objects is quite different in other Aboriginal communities on the mainland. For example, in central Australia the Magellanic Clouds are looked upon as the homes of the Kungara brothers. The Aborigines believe that the Kungara brothers watch over them from the sky and punish or reward them according to their deeds (Mountford 1976).

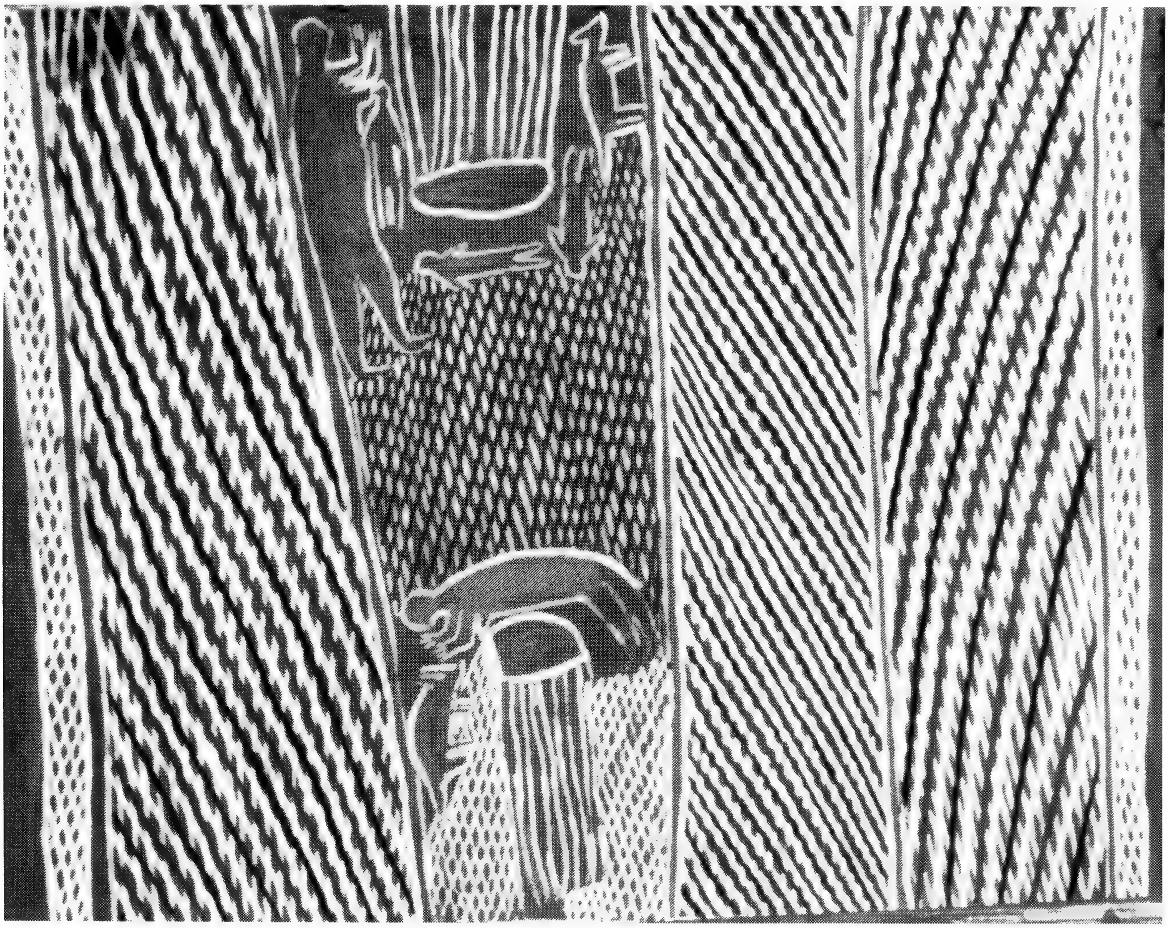

Figure 4. The Magellanic Clouds.

The Milky Way which spreads like a broad white band from one horizon to the other is one of the most spectacular celestial objects to grace the night sky over Australia. It is seen by almost all Aboriginal groups as a river in the sky where the sky people live. In creation times the Milky Way was seen as a water course near Blue Mud Bay by the Aboriginal people in Yirrkala. This river is reflected in the sky as the Milky Way according to the Aborigines in Yirrkala. The story of two brothers who were caught in a storm after a fishing trip is depicted in the Milky Way. They did not survive the storm and drowned. Their bodies and their canoe are the dark patches in the Milky Way.

Aboriginal Constellations

Mountford was informed of three Aboriginal constellations which bore their own Aboriginal names. Very little information of these constellations is recorded by him in the notes of the expedition. He mentions the Aboriginal constellation of Scorpion which it would appear is in the European constellation of Lupus. Unfortunately the names of the stars which make up this constellation are not provided. The Aboriginal constellation of the crab (Unwala) gives us an interesting insight into some aspects of the organisation of Aboriginal astronomy. They were more interested in the patterns made by the stars rather than their brightness and this led them to disregard the brighter more obvious nearby stars. Thus, at Groote Eylandt, the Aboriginal people gave the name Unwala to a group of rather inconspicuous stars (with an average magnitude of 4.4) at the head of the European constellation Hydra. They disregarded the two bright nearby stars, viz: Procyon and Regulus which have magnitudes of 0.36 and 1.35 respectively. They were also more interested in identifying a group of stars to support their stories.

The stars in the European constellation of Scorpio have been grouped by the Aborigines in Yirrkalla into two Aboriginal constellations, viz: the Crocodile and the Opossum and the Ibis-men. The Crocodile constellation is made up of the stars from the sting (i.e. Lambda and Upsilon Scorpio) to the star Sigma Scorpio near the bright red star Antares. In the second group, Antares is the Opossum man. The two stars (Tau Scorpio and Rho Scorpio) on either side of Antares make up the Ibis-men.

Stars and Seasons

From the rather patchy information we can glean from the paintings, it is clear that the Aboriginal people in north-east Australia had developed the beginnings of a correlation between the appearance of certain stars in the sky with the seasons and the beginning or end of certain activities. Thus, on Groote Eylandt when the stars Lambda and Upsilon Scorpi in the constellation Scorpio made their appearance in the sky towards the end of April the Aborigines knew that the wet season had ended and the dry south-easterly wind (Marimariga) would begin to blow. In Yirrkala the appearance of Scorpio informed them that the Macassan fishermen were coming to collect the trepang. When Arcturus could be seen in the eastern sky in the early morning, it was a sign to the Aborigines in Arnhem Land that it was time to make fish traps and baskets from the spikerush. This correlation between the appearance of certain stars and the seasons was also used by the Aborigines for ordering their daily activities.

The association of the stars with the seasons was also used in other parts of Australia. Thus, when the Pleiades appeared in the dawn sky, the Pitjantjatjura in the Western Desert region knew that the annual dingo breeding season had begun. A few weeks later they would raid the lairs to feast on the young pups. In western Victoria, the appearance of Arcturus told the Aborigines where to find the pupa of the wood ant which served as a source of food.

Conclusion

The collection of thirty-six bark and paper paintings collected by the American-Australian Expedition to Arnhem Land has provided us with some aspects of the pre-contact astronomy of the Aboriginal people living in this part of the world. The paintings are unique in that they not only provide us with a visual representation of Aboriginal social cultural astronomy but they

are supplemented with the oral testimony of their meaning. This group of bark paintings is the largest single visual collection of pre-contact astronomy in Australia. It is thus important that they should be brought together and placed in a single institution and called the Aboriginal Astronomical Heritage Collection.

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Stellar Astrophysics

RAGBIR BHATHAL

Abstract: Michael Bessell has been the most cited author at the Research School of Astronomy and Astrophysics at the Australian National University for the past 12 years and is one of 33 Australian Citation Laureates for work carried out between 1981 and 1988.

He is internationally recognized for his work in photometry and his filter systems have become standard filters in use at most observatories throughout the world. His research interests include the study of the evolution of different mass stars and the build up of elements in these stars, searches for the most metal-poor stars, searches for proto-planetary disks and proto-planets and brown dwarfs through a study of young M dwarfs, temperature calibration of stars, astronomical photometry and instrumentation. He has made significant contributions in each of these areas of astronomical research.

Keywords: Standard photometric systems, stellar evolution, AGB stars, M dwarfs

EARLY LIFE

Michael Bessell grew up in a home where there was always talk at the dinner table about education and the 'politics of the teaching profession.' His grandfather who was a headmaster was the President of the Tasmanian Teacher's Federation and he knew 'not only Joe Lyons but also all the socialist members of Parliament while his father was the Secretary of the Workers Education Association.' So in this environment it was natural that they believed 'that the only way for people to achieve in the world was to gain a good education.' This philosophy was instilled in Bessell at a very young age. According to Bessell, 'my parents brought us up to have the idea that the only way to succeed was to do well at school.' He attended government schools and for his secondary education he attended Hobart High School, a selective high school.

As a young boy he read 'lots and lots of books and our family had a great respect for books.' Interestingly he read books on archaeology. 'I can remember looking through the Illustrated London News and seeing pictures of scientists at work digging up tombs from different places and so I always had the idea of being a scientist even though I wasn't sure what a scientist was.' He was also curious about how things work. The mechanical advantage that pulleys and levers provide fascinated him. 'I was fascinated by the idea of the way pulleys and levers worked and how people could master the environment by using them.' Algebra and mathematics held a similar fascination for him. 'The idea that you let X be something and you could solve for it, really came as a wonderful idea and I was forever solving problems after this.'

INTEREST IN ASTRONOMY

His interest in astronomy came later. It was fired by Bart Bok, the then Director of the Mount Stromlo Observatory who according to Bessell, 'was an amazing publicist and enthusiast. It was Bok's aim I think in life to speak to as many people in Australia as possible about astronomy.' He attended some of his lectures at university and was 'absolutely fascinated by his showmanship and the fascinating pictures that he would show.' 'That is what stimulated a great interest of my doing astronomy.'

He went up to the University of Tasmania for his undergraduate studies on a teacher's scholarship. It was natural for him he said to go into teaching. 'My grandfather was a teacher, my mother was a teacher and my aunts were teachers.' However, this was to change in his honours year when for his honours project he did a radio astronomy project under Ellis, the professor of physics who was very well known for his 'mathematical theories of the ionosphere.' At the time he was studying in the physics department there were two other

well known physicists, viz: F.D. Cruickshank and Hans Buchdahl. Cruickshank was 'very famous for his invention of paraxial coefficients of optics.' According to Bessell 'this for the first time enabled people other than the scientists at Zeiss to make lens systems. And people who graduated through the physics department at the University of Tasmania went on to found optic companies in America to build cameras for the U2s. It led to a whole lot of work during the war of designing optics and they were able reproduce these Zeiss patents from first principles.' Buchdahl was famous for his work on the theory of general relativity and later moved to the Australian National University.

For his project he measured the galactic radio radiation at 1.5 and 2.5 Megahertz. This work along with observations made with another student, Michael Waterworth led to his first paper in *Nature* (Ellis et al. 1962). The article appeared under the names of Ellis, Waterworth and Bessell. It happened that Fred Hoyle was visiting Tasmania at that time and he reviewed their observations and gave them an explanation of the phenomena. It was this 'first chance to meet Fred Hoyle, a well known British astronomer'. He was most impressed with Hoyle.

MOUNT STROMLO OBSERVATORY

For his PhD he went to the Australian National University's Mount Stromlo Observatory where Bart Bok was a professor of physics. It was Bessell said, 'the only place really in Australia to do optical astronomy' at that time. His topic was on variable stars and it was a field in which he was to become an international authority. Variable stars are stars whose luminosity changes. By studying variable stars astronomers are able to find important aspects of a star's mass, its radius and temperature. His particular variable stars were called Dwarf Cepheids and Delta Scuti stars. These stars, he said, 'had been discovered quite recently and they had periods between one and about four hours.' Some of them had large amplitudes of up to half a magnitude and 'light curves which resembled the famous RR Lyrae stars which are found in globular clusters.' The stars he had chosen for his study 'were unknown and they were not in clusters and hence people didn't know what their luminosity was.' 'They didn't know what evolutionary stage they were at and it was a fascinating thesis to try and work out what these stars were', according to Bessell. Others who had studied them considered them to be similar to the very old and low mass RR Lyrae stars, but this made very little sense because most of them had very low motions like the Sun and stars which are more massive than the Sun. What he discovered was 'that people were measuring the effective gravity by fitting the energy distribution and it turns out that there was an error in the fundamental calibration of the energy distribution of Alpha Lyrae.' He was able to correct 'this error in the energy distribution, correct gravities for the stars and show that they had mass of one and half times that of normal main sequence stars which happened to be evolving through the instability strip.' This work got him interested in the energy distribution of stars, model atmospheres of stars and the fundamental importance of getting the calibrations right. This also meant obtaining fundamental data for stars. It is interesting to note that the instrument (photoelectric scanner) that he used for his work is now on display at the Museum of Applied Arts and Science in Sydney.

AT YERKES OBSERVATORY

He spent sometime at Yerkes Observatory to work as an associate with Bob O'Dell who had been appointed the new Director of the Observatory. He was involved in commissioning a new spectrograph that was being built for that telescope and also carrying out a research program on symbiotic stars. While there he also had the opportunity of meeting Chandrashekar who was the editor of the Astrophysical Journal and a Nobel Prize winner. One of the benefits he derived by being at Yerkes was that he was able to meet quite a number of astronomers who were working in various fields, such as the spectral classification of stars. 'So meeting these

people and being associated with them I think gave me a much broader interest in the kind of stellar physics which I was interested in.'

In 1969 he was appointed a Research Fellow at the Mount Stromlo Observatory at the Australian National University. He has remained there ever since and was eventually appointed to a professorship in 1998. He came back to Australia because it was 'a research only position and that was very attractive position to come back to.'

HIGH CITATIONS

He has a track record of highly cited publications and was awarded the Institute of Scientific Information, Australian Citation Laurette. One of the papers he wrote in 1979 while he was at Kitt Peak generated the most of his citations (Bessell 1979). He had gone to Kitt Peak because one of his students, Harvey Butcher, Jeremy Mould and Garth Ellingworth were there. Butcher is now the Director of the Mount Stromlo and Siding Spring Observatories. Butcher, he said was 'doing some exciting things with new image area detectors. He was also looking at other detectors.' It became obvious to him that one of the problems with the photometric detectors that were being used was that they were very poorly calibrated and the northern hemisphere 'standards were really quite terrible.' In South Africa Cousins had been carrying out excellent work in setting up standards for photometric observations. Unfortunately the northern hemisphere astronomers were not aware of his work.

Most astronomers had been 'brought up to believe that broadband photometry using very wide bands of 800 Angstroms was impossible to do high precision work with.' The Europeans, Stromgren and a lot of Americans assumed that the 'only way you could do high precision work was to use narrowbands.' Bessell was able to disprove this assumption. 'I started to observe Cousins' standards using both northern hemisphere broadband standards. Cousins' standards were five times more precise than the northern hemisphere broadband standards. So I realised that it was not the broadband that was the problem it was just the lousy work that the northern hemisphere astronomers had been doing.' Butcher encouraged him to write a paper about this and to 'provide transformations between other photometric systems' and to also say what he considered 'to be the best photometric system to use.' He did this and had over 972 citations for his paper (Bessell 1979). He went on to write other papers after that, again going into more detail on the problems with the northern hemisphere red photometric system. His work expanded into 'trying to understand the bands used for photometric systems so that we could synthesise them with model atmospheric fluxes and do synthetic photometry and from spectral photometric observations of galaxies and quasars and everything else.' 'And to do that,' he said, 'you have to reverse engineer standard photometric systems and so it all kind of tied it all up over a period of 20 to 25 years (Bessell & Brett 1988, Bessell 1990, Bessell 2005)'. He worked in this area up to the time that photoelectric photometry reached its zenith. It has now more or less vanished. It has been taken over by CCDs and it is very likely that 'all photometry will be done by survey telescopes.' The main advantage of the CCD is that one is 'able to do multiple objects. Furthermore, the CCD is completely linear.'

About the time when this period came to an end the Sloan Survey had made its appearance. Similarly the Hipparcos Catalogue was also released about the same time. According to Bessell, 'For the first time with the Hipparcos Catalogue the whole sky was covered with observations which are well standardized, going to very faint magnitudes.' However, with a new photometric system one has to work out how the old photometric systems relate to the new photometric systems. Bessell wrote a paper on Hipparcos colours and found that there were some problems with the Hipparcos photometry. He is now involved with building the Skymapper telescope at Siding Spring with Brian Schmidt. According to Bessell, 'Brian Schmidt plans to map the sky with a system similar to the Sloan system but with better sensitivity to measure the abundances and effective gravities

of stars. He believes that we are going to be the first group that will provide the necessary precise standards for planned southern hemisphere large telescope surveys'. The Skymapper survey will be taking snapshots. 'We will have a single CCD which will take an image of the sky. Then move the telescope and another image of the sky will be taken. So all stars in an image will have precisely the same image profile. And so Brian Schmidt believes we will be able to do much better photometry in this way than any other survey has ever been able to do.' Skymapper will have a seven degree field of view and will also give very precise positions as well as photometry.

Bessell's work on long period variables in the Magellanic Clouds led to an important identification with respect to the Asymptotic Giant Branch (AGB) stars and new insights into stellar evolution (Wood et al. 1983). AGB stars refer to the last nuclear-burning stage in the evolution of stars after they leave the main sequence. According to Bessell, 'stars in this stage are burning helium and hydrogen in shells surrounding a core of carbon and nitrogen.' 'One of the interesting things about this time of its evolution,' he continued, 'is that this kind of burning is very unstable and it can flare up and drop back down again. During the inter pulse periods material can be dredged up to the surface and when we look at the atmospheres of these stars we can see the elements that are being created deep inside these stars. So these stars are actually a primordial source of carbon and nitrogen and also some of the heavier elements, such as lead and uranium.' Along with Peter Wood he found another interesting thing about stellar evolution. They were able to work out 'what mass stars turn into supernovae and which stars turn into white dwarfs.' This was not known until the work carried out by Wood and Bessell. Bessell's work on AGB stars was a big breakthrough in AGB evolution.

He has been involved in the study of metal or heavy element abundance in stars. About twenty years ago he discovered CD-38 245 which was the most deficient star ever formed (Bessell & Norris, 1984). It was deficient by a factor of 30,000 with respect to the Sun. It implied that it was formed soon after our Galaxy came into existence. So a study of the abundances of the elements in its atmosphere can tell us about the kind of stars that were formed in the very first generation of star formation. About eighteen years later Bessell's group discovered HE 0107-5240 (Christlieb et al. 2004, Bessell et al. 2004). This is a very low mass star with iron abundances as low as 1/200 000 of the solar abundance of iron. It had implications for the study of star formation theory and the synthesis of chemical elements in the early universe. According to Bessell, 'interestingly enough these stars, even though they were low in iron, they were very high in carbon, oxygen, nitrogen and sodium. And there seems to be an explanation for this.' 'So what we believe', he said, 'is HE0107-5240 was formed from the supernova ejecta of very massive 25 solar mass first generation supergiant formed soon after the Big Bang. It produced a lot of carbon and nitrogen through normal chemical evolution of hydrogen and helium so it had an outside envelope of carbon, nitrogen and oxygen. This was ejected partly with stellar winds and then the star underwent a massive supernova explosion but there was so much envelope on top of the star that the supernova did not completely break out. A lot of the material got remixed and reprocessed but only a little was ejected. Most of it fell back into a black hole. So you have a 25 solar mass star which ends up as a 20 solar mass black hole. A lot of the carbon, nitrogen and oxygen was expelled in the interstellar medium but only a very small percentage of iron escaped.'

Bessell has worked on stars varying from O stars to M stars. In fact, the whole width and depth of the main sequence. Whilst hunting for the coolest and oldest white dwarfs on the Anglo Australian Telescope 'we found many M dwarfs and a lot of M sub-dwarfs which had never been seen before. This led to publications on the properties of M dwarfs and the discovery of extremely metal-deficient low mass stars.' Because of his knowledge of M dwarfs he was invited by Inseok Song and Ben Zuckerman from the University of California to collaborate with them on the study of young stars which

will enable imaging and spectroscopic studies of the origin and early evolution of planetary systems (Zuckerman & Song 2004). Beta Pic was a very interesting star that had recently been discovered to have a duty disk around it, but because it was an isolated A star noone knew its age or what evolutionary stage it was at. From the work they did together they found another 30 stars which according to Bessell, 'were sharing the same space motions as Beta Pic and so in effect it gave us a mini cluster.' They were then able to get an age for the cluster or the moving group on the basis of the luminosities of the pre-main sequence M stars that they had found. This gave them the age of Beta Pic. 'This makes it much more interesting from an evolutionary point of view because we can now understand its history', he said.

Apart from his research work he has also served as a consultant for astronomy for New Zealand. In 2002 he did a review of New Zealand's capability to build a spectrograph for SALT (Southern African Large Telescope). He visited New Zealand and inspected the facilities in Christchurch, Auckland and Wellington to asses whether they had the background and the capabilities to build scientific instruments. He found they did and 'wrote a very positive appraisal of that possibility and that enabled them to take that to the Vice-Chancellor of the University of Canterbury and get his support for the University joining SALT with a hope that other universities would join in. Unfortunately the other universities did not take up the offer so the University of Canterbury has now joined SALT but the rest of the New Zealand astronomers have not.' In 2004 the New Zealand Ministry of Research and Science invited him to review New Zealand's need for a national observatory because Carter Observatory, which was the national observatory, was unable to continue doing active research and wished to become a charitable trust concentrating on astronomical outreach. One of the issues was that the University of Canterbury's Mount John Observatory was performing most of the functions of a national observatory but was 'receiving nothing from the government for performing that role.' Bessell pointed out in his report that 'it was very difficult for a single astronomer or a single physicist within a department in New Zealand to get much support for astronomical research. A national observatory could provide the kind of support and encouragement for joint collaborations that would be good for New Zealand science and education. It would stimulate the same kind of growth in astronomical interest that Australia certainly has had over the last 20 years.' The government is still considering the report.

Bessell is a very active and productive researcher and thus it is interesting to find out what is his research strategy. 'I have been very lucky in my research in being in the southern hemisphere and having access to front line instrumentation and having a reasonable amount of observing time for most of my projects. I also have very good colleagues many of whom are theoreticians. I have also visited different observatories and talked with many people there and was able to either get ideas from them or work with them on interesting projects. So it is a kind of synergy of interacting and encouraging others to collaborate, of creating and fostering the networking of astronomers around the world.'

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Does Grey Nurse Shark (*Carcharias taurus*) Diving Tourism Promote Biocentric Values Within Participants?

KIRBY SMITH, MARK SCARR AND DR CAROL SCARPACI

Abstract: In Australia, humans can dive with critically endangered grey nurse sharks (*Carcharias taurus*) at Fish Rock, New South Wales. This industry has the potential to improve the environmental knowledge of participants and encourage pro-environmental attitudes within tourists. This study surveyed tourists pre and post participation in grey nurse shark dives to ascertain if the experience positively influenced the grey nurse shark knowledge and biocentric attitudes of tourists (short-term). Educational talks were provided to tourists of alternating boat trips to assess if education had a significant impact upon the knowledge and biocentrism of these tourists compared with those that were not provided with a talk. Survey data were collected across eight grey nurse shark dive boat trips from December 2008 to January 2009. Results indicated that those individuals likely to participate in a grey nurse shark dive were generally already knowledgeable and biocentric, hence the scope for further improvement was quite narrow. Significant improvements to the grey nurse shark knowledge and biocentric attitudes of tourists post dive were detected, however the majority of these improvements occurred within tourists already considered to be highly biocentric and knowledgeable pre dive experience. The provision of educational talks significantly improved the knowledge of participants but not their biocentrism. These findings are of importance as they highlight that the contribution the industry may provide to conservation by improving the biocentric attitudes and environmental knowledge of tourists may be minimal. Furthermore, it is important that accurate educational resources are developed and provided to tourists pre and post dive to avoid the development of misconceptions by tourists during grey nurse shark dives.

Keywords: Grey nurse shark, *Carcharias taurus*, biocentric, biocentrism, pro-environmental, shark dive, nature-based tourism.

INTRODUCTION

In Australia, humans can SCUBA dive with critically endangered grey nurse sharks (*Carcharias taurus* Rafinesque, 1810) at Fish Rock, New South Wales (Environment Australia 2002). Historically, the grey nurse shark in Australia was inaccurately portrayed as a 'man-eater', largely due to its formidable appearance (Environment Australia 2002, Boissonneault et al. 2005, Kessler 2005). Subsequently, grey nurse sharks were targeted by spear and line fishers in attempts to remove the species from the east coast of Australia, hence its current conservation status (Environment Australia 2002, Stow et al. 2006). The grey nurse shark dive industry has the potential to quash such perceptions, to exert positive influences on the pro-environmental attitudes of tourists and to improve their knowledge of the species and the marine environment (Zeppel & Muloin 2008). This in turn may encourage tourists to adopt more pro-environmental behaviours (Mayes et al. 2004), such as abiding by regulatory management practices.

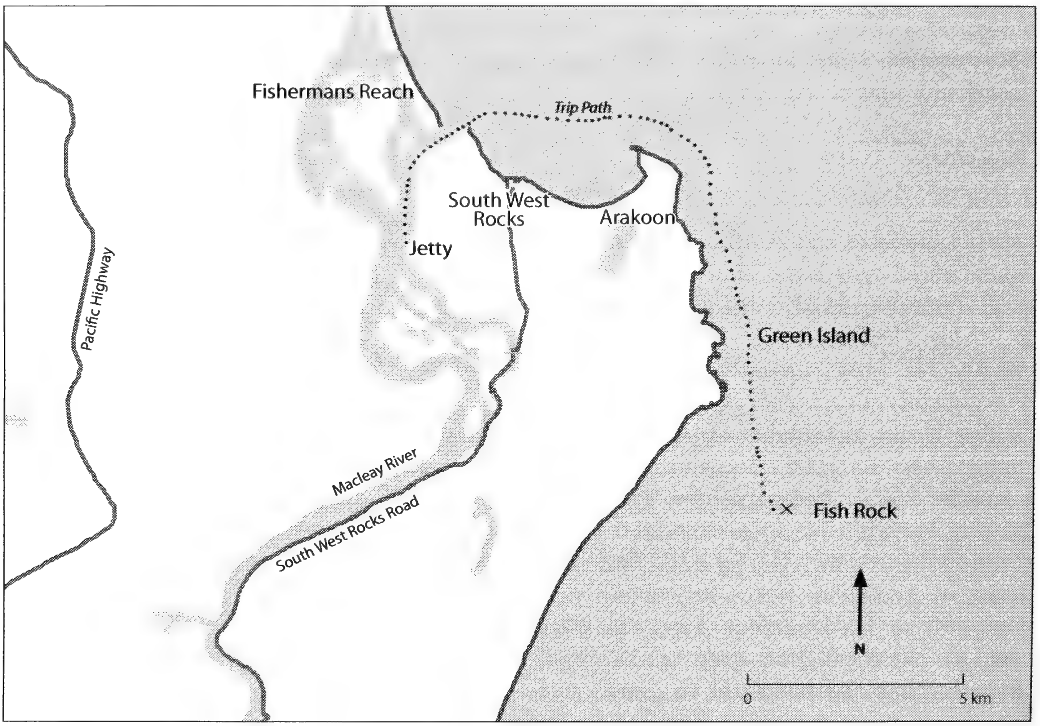
Scientific research is necessary to assess the validity of the claim that nature-based tourism has the potential to positively impact upon tourists' pro-environmental attitudes and environmental knowledge (Higham et al. 2009). Research methodologies of earlier studies incorporated the use of surveys to ascertain the environmental attitudes and knowledge of tourism participants (Wilson & Tisdell 2003, Finkler & Higham 2004, Mayes et al. 2004, Hughes & Saunders 2005, Christensen et al.

2007, Powell & Ham 2008, Mayes & Richins 2009). Some of these studies (Wilson & Tisdell 2003, Finkler & Higham 2004, Mayes et al. 2004, Christensen et al. 2007, Mayes & Richins 2009) surveyed participants immediately post tourism experience. The current study surveyed grey nurse shark dive tourists pre and post dive to ascertain the influence of this industry on improving pro-environmental views and values, i.e. biocentrism (Des Jardins 2001), and knowledge within participants. The potential of education to further increase biocentrism and knowledge within tourists was also investigated. It appears that this is the first study to document and compare biocentric attitudes and shark knowledge within shark dive tourists pre and post dive.

METHODS

A total of 27 SCUBA diver-grey nurse shark interactions across 15 boat trips were observed and documented at Fish Rock in New South Wales, Australia, from December 2008 to January 2009. Grey nurse shark dive tour boats depart from South West Rocks and travel to Fish Rock as shown in Map 1. The researcher travelled to and from Fish Rock onboard a 7.5 metre catamaran belonging to a local tourism operation.

To assess if this form of nature-based tourism improved the environmental knowledge of participants and encouraged them to adopt more biocentric values and attitudes in the short-term, participants were asked to complete a written survey (of approximately five minutes) prior to a grey nurse shark dive and then again post dive: a method found to be effective in earlier nature-based tourism research (Hughes & Saunders 2005, Powell & Ham 2008). Pre and post dive surveys were completed by tourists onboard the dive vessel. Survey participation was voluntary and a total of 47 paired surveys (consisting of both pre and post dive surveys) were completed by grey nurse shark dive tourists across eight of fourteen boat trips. The first two dives (spanning one boat trip) were carried out as practice dives and hence no data were recorded. Due to the participation in multiple dives by some divers and the potential for data collection to disrupt the schedules of tourism operations, survey data were collected during eight of the fourteen boat trips.



Map 1: Return trip from South West Rocks jetty to Fish Rock.

The survey design was adapted from Christensen et al.'s (2007) study on the effectiveness of a whale watching education program in Oregon, Canada, as it documented short-term biocentric values and knowledge of tourists and was considered an appropriate model. Participants' answers to pre dive surveys were compared with post dive surveys to determine if grey nurse shark dives had a significant impact upon participants' knowledge and perceptions of the marine environment and sharks (both generally and in relation to grey nurse sharks in particular). In addition to this, educational talks (of approximately five to ten minutes in length) were provided by the researcher to tourists of alternating trips. Educational talks were conducted on alternate boat trips in order to assess the effect these talks had on improving biocentrism and knowledge within participants. Educational talks provided information regarding grey nurse shark biology, distribution, population status, conservation status and management strategies, and were delivered utilising visual aids (laminated A4 sheets). Comparisons were then made between the post dive survey responses of those whom were provided with an educational talk and those whom were not.

To assess the biocentrism of tourists the following statements were included in the survey as adapted from Christensen et al. (2007):

- The marine environment requires our protection.
- It is important to protect the marine environment.
- It is important to protect sharks.
- It is important to spend money to protect sharks.
- Sharks are important for Australia.
- Sharks need a healthy marine environment to survive.
- My daily actions affect sharks.
- My daily actions affect the marine environment.

Participants were required to assign a score for each of the eight statements based on a scale of 1 to 5 where 1 = strongly disagree, 2 = disagree, 3 = undecided, 4 = agree, 5 = strongly agree (Musa 2002, Lück 2003, Finkler & Higham 2004, Christensen et al. 2007, Morris et al. 2007, Powell & Ham 2008). Therefore, the maximum overall score a tourist could achieve for the biocentric section of the survey was 40. For analyses purposes, mean response scores of 1–2.9 were considered non-biocentric, 3–3.9 represented neutral values and attitudes, and mean scores of 4–5 were deemed biocentric.

Specific questions relating to grey nurse sharks were also included and participants were asked to answer either 'yes' or 'no'. Participants were presented with the following seven knowledge questions and statements:

- Grey nurse sharks are a protected species.
- Grey nurse sharks are an endangered species.
- Is the population size of grey nurse sharks at an acceptable level in eastern Australia for their long-term survival?
- Are grey nurse sharks a threat to humans?
- Can a tourist pursue grey nurse sharks?
- Can a tourist diver touch a grey nurse shark?
- Are sharks an important part of the marine environment?

Correct answers were assigned a score of 1 and incorrect answers a score of 0, therefore, an overall result of 7 equated to a maximum score of 100% for the knowledge section of the survey. Tourists whose mean responses ranged from 0–0.4 were deemed to possess poor knowledge of grey nurse sharks and responses of 0.5–1.0 represented good grey nurse shark knowledge.

Statistical Analysis

For both aspects of this study the mean biocentric and knowledge responses of each diver were used as indicators of biocentrism and knowledge levels of tourists.

Both biocentric and knowledge pre and post grey nurse shark dive survey responses were compared using Wilcoxon paired-sample tests (Zar 1974).

The post grey nurse shark dive biocentric and knowledge survey responses of tourists provided with an educational talk and those whom were not were compared using Mann-Whitney tests (Zar 1974).

RESULTS

A total of 27 dives (N = 118 divers) spanned across 15 boat trips and total time spent in the field was 66.8 hours. The mean number of divers that participated in a grey nurse shark dive expedition (including the researcher and dive

operation employees) was 8.4 (standard deviation = 2.8 divers, range 3–12 divers, n = 14 boat trips). Of those divers presented with the option to participate in the survey study (N = 55) a total of 47 took part. (76.4%). Of these 47 surveys, the pre and post dive knowledge responses of three survey pairs could not be compared as some questions were not completed. When comparing the responses of tourists whom were provided with an educational talk with those whom were not the post dive knowledge survey responses of two participants could not be utilised for the same reason. The proportion of surveyed tourists exposed to an educational talk (tourists of four boat trips) was 57.4% (N = 27 divers). The proportion of those not provided with an educational talk (tourists of four boat trips) equaled 42.6% (N = 20 divers).

Comparison of Survey Responses Before & After Grey Nurse Shark Dive

Biocentric Statements

A Wilcoxon paired-sample test revealed that there was a significant difference (α=0.05, 0.01<P($\leq$338)<0.02) between the pre and post dive responses for the biocentric survey statements, as shown in Figure 1.

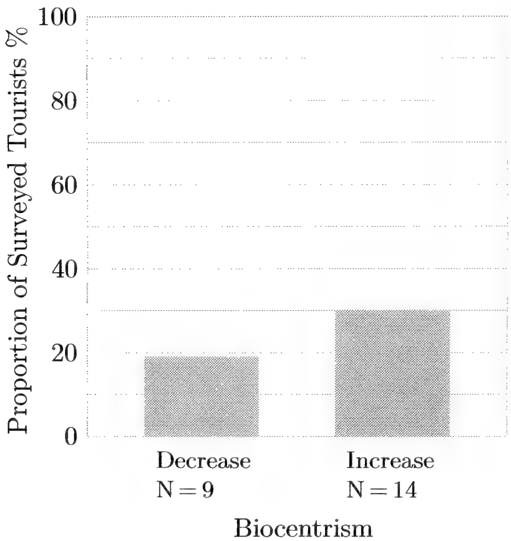


Figure 1. Change in biocentrism in tourists (%) post grey nurse shark dives (n = 47).

Results showed that 29.8% of tourists became more biocentric in their responses after the dive, 19.2% of tourists decreased their level of biocentrism, and 51.1% of tourists' answers did not change post dive. Expanding upon this, results in Figure 2 indicated that 83.3% of the tourists whose responses did not alter were already considered either completely biocentric (29.2%) or highly biocentric (54.2%); therefore the margin for improvement was either non-existent or very low.

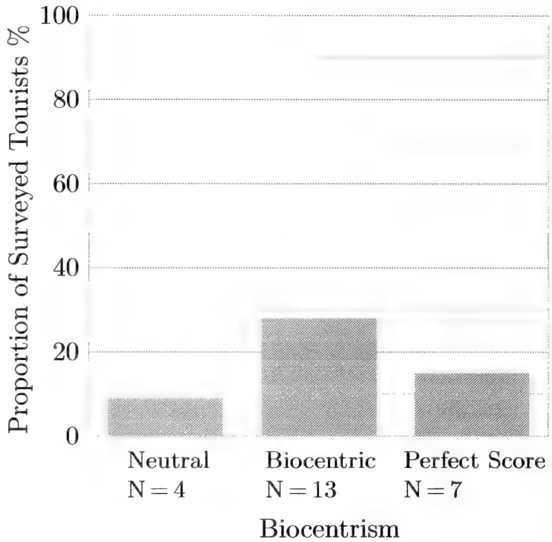


Figure 2. Proportion of tourists (%) whose post dive responses to the biocentric statements did not alter from their pre dive responses to the biocentric statements (n = 47).

Although results revealed a significant (α=0.05) change in survey respondents' answers post participation in a grey nurse shark dive (both increases and decreases in biocentrism were detected), the total proportions of tourists whom were considered to be non-biocentric, neutral and biocentric remained unchanged overall. Figure 3 indicates that whilst an increase in the level of biocentrism was documented, 57.1% of this increase was accounted for in pre dive biocentric tourists who further improved their biocentrism post dive. A further 28.6% of the detected increase in biocentrism was due to a slight improvement in biocentrism by tourists whose responses were considered neutral pre and post dive.

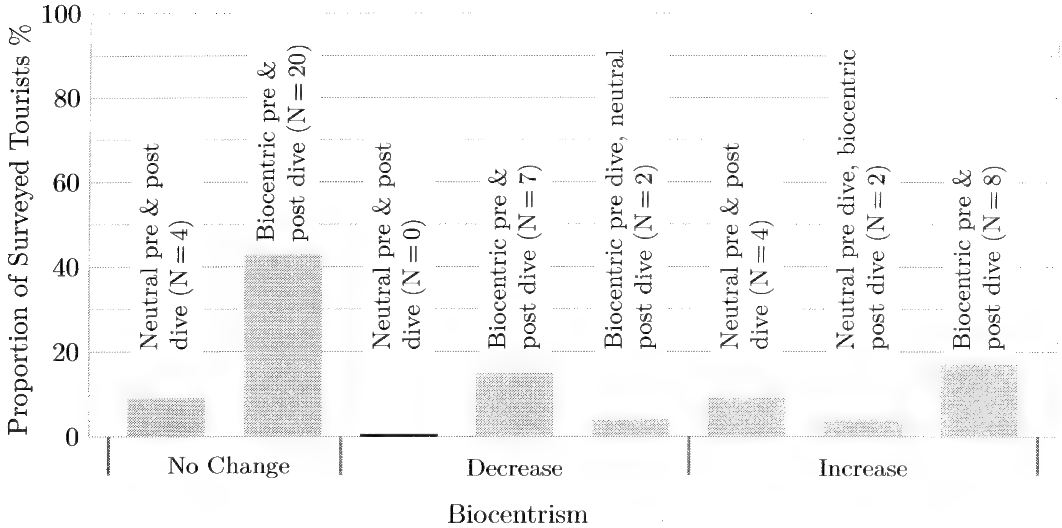


Figure 3. Proportion of surveyed tourists (%) per category (i.e. neutral pre dive or biocentric pre dive) who either experienced no change, a decrease or an increase in biocentrism post participation in a grey nurse shark dive (n = 47).

The remaining 14.3% increase in biocentrism was attributed to a shift from neutral to biocentric values within tourists (accounting for 4% of surveyed tourists). The proportion of tourists (4%) who experienced a shift from neutral to biocentric values (i.e. an increase in biocentrism) is mirrored by the proportion of tourists (4%) who exhibited a shift from biocentric to neutral values (i.e. a decrease in biocentrism); hence these incidences of change nullify each other in regard to the overall proportions of neutral and biocentric tourists.

Thus, results stated that the proportions of non-biocentric, neutral and biocentric tourists pre and post dives did not change, as shown in Figure 4. Prior to the dives 78.7% of tourists were considered biocentric and this proportion did not alter post dives, there were no (0%) non-biocentric tourists both pre and post dives and 21.3% of tourists remained neutral in their responses to the biocentric survey statements.

As depicted in Figure 5, the mean responses of tourists to 75% of the biocentric statements were considered biocentric (i.e. equal to or greater than a score of 4). The remaining 25% of biocentric statements received mean responses indicative of neutral (i.e. mean scores between 3.0–3.9) values and attitudes within tourists in relation to the impact of their daily actions upon sharks and the marine environment. The degree of biocentricity in the pre and post dive responses of tourists to 37.5% of statements increased (i.e. 'the marine environment requires our protection', 'it is important to protect sharks', 'my daily actions affect the marine environment'); the mean response of tourists to 25% of statements decreased post dive (i.e. 'it is important to protect the marine environment', 'sharks are important for Australia'); and, the mean response of tourists to the remaining 37.5% of biocentric statements did not alter (i.e. 'it is important to spend money to protect sharks', 'sharks need a healthy marine environment to survive', 'my daily actions affect sharks'). Although an increase in biocentrism was documented in the mean responses of tourists to 37.5% of the statements, a shift from neutral values and attitudes to biocentric views did not occur. Similarly, whilst a decrease in the level of biocentric responses to 25% of the statements occurred this was not reflected in a shift from biocentric to neutral views.

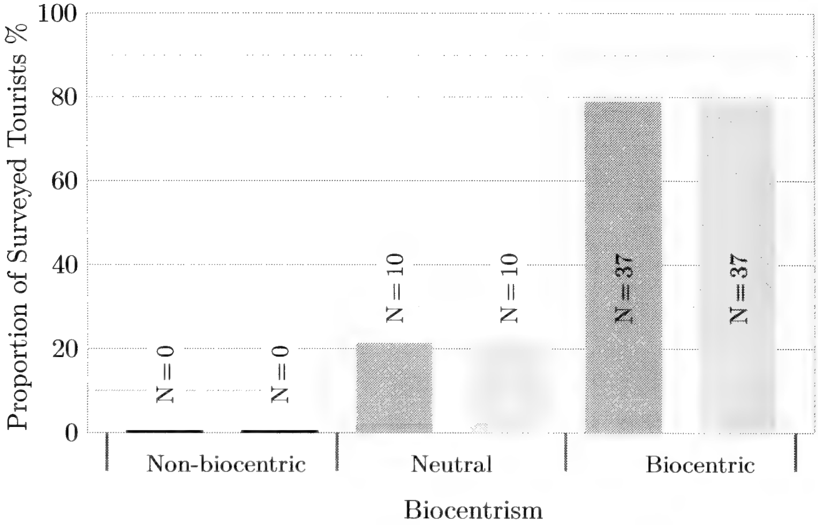


Figure 4. Proportion of non-biocentric, neutral and biocentric tourists (%) for pre and post grey nurse shark dives (n = 47). Pre dives Post dives

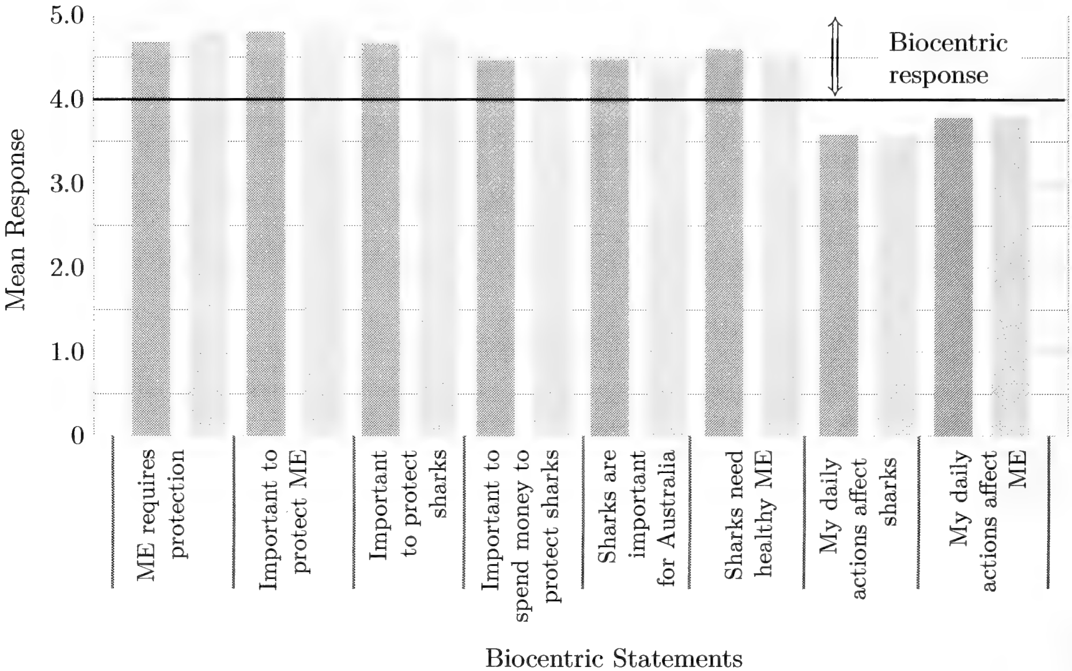


Figure 5. Biocentrism of tourists' responses pre and post dive to each biocentric statement. Biocentrism: 0–2.9 = non-biocentric, 3.0–3.9 = neutral, 4.0–5.0 = biocentric, ME = marine environment, n = 47. The point at which responses are deemed biocentric is indicated by the thickened black line. Pre dives Post dives

Grey Nurse Shark Knowledge Questions and Statements

A Wilcoxon paired-sample test indicated that there was a significant difference (α=0.05; 0.01<P(T≤326)<0.02) between the pre and post dive responses for the grey nurse shark knowledge survey questions and statements, as shown in Figure 6.

Results found that 20.5% of tourists experienced a decrease in knowledge post dive and 9.1% of tourists became more knowledgeable after the dive. As shown in Figure 7, 70.5% of tourists' levels of knowledge did not alter; 25% of tourists already possessed good levels of grey nurse shark knowledge and a further 45.5% obtained the correct answer to all knowledge questions and statements, therefore the margin for improving knowledge was either minimal or non-existent.

Of the tourists whose knowledge decreased after participating in a grey nurse shark dive, 22.2% were considered to have poor grey nurse shark knowledge both pre and post dive and 77.8% were deemed knowledgeable both prior to and after the dives. Figure 8 indicates that a shift in tourists from good knowledge of grey nurse sharks pre dive to poor knowledge post dive was not documented. Therefore, although a decrease in knowledge did occur, it did not influence the overall proportions of tourists who possessed poor knowledge or good knowledge pre and post dive. However, in regards to the tourists whose knowledge increased after participating in a grey nurse shark dive, 25% went from having poor knowledge prior to the dives to possessing good knowledge after the dives, thereby accounting for the 2% increase in the proportion of knowledgeable tourists overall post dive as depicted in Figure 9. The remaining 75% of tourists that experienced an increase in grey nurse shark knowledge were already deemed knowledgeable pre dive and so this result did not impact upon the overall proportions of tourists with poor or good knowledge.

Therefore, although the proportion of tourists whose knowledge decreased (20.5%) post participation in a grey nurse shark dive was greater than that of those whose knowledge increased (9.1%), the overall proportion of tourists possessing good knowledge increased by 2% post participation in a grey nurse shark dive, as indicated in Figure 9.

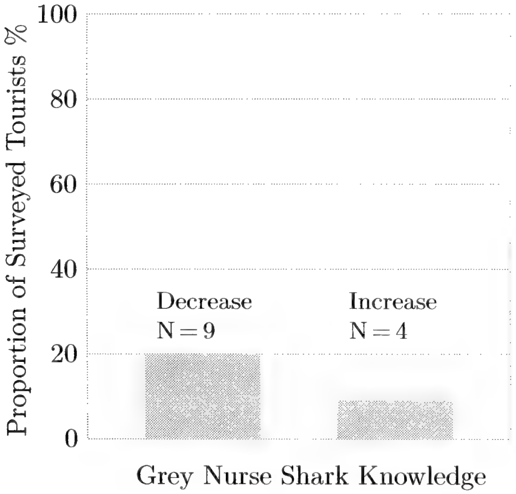


Figure 6. Change in grey nurse shark knowledge of tourists (%) post grey nurse shark dive (n = 44).

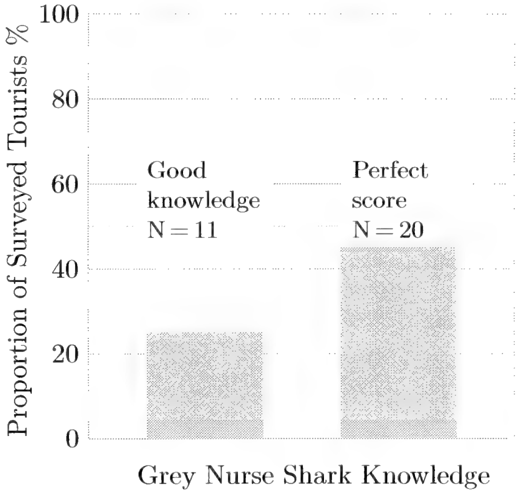


Figure 7. Proportion of tourists (%) whose post dive responses to the knowledge questions and statements did not alter from their pre dive responses to the knowledge questions and statements (n = 44).

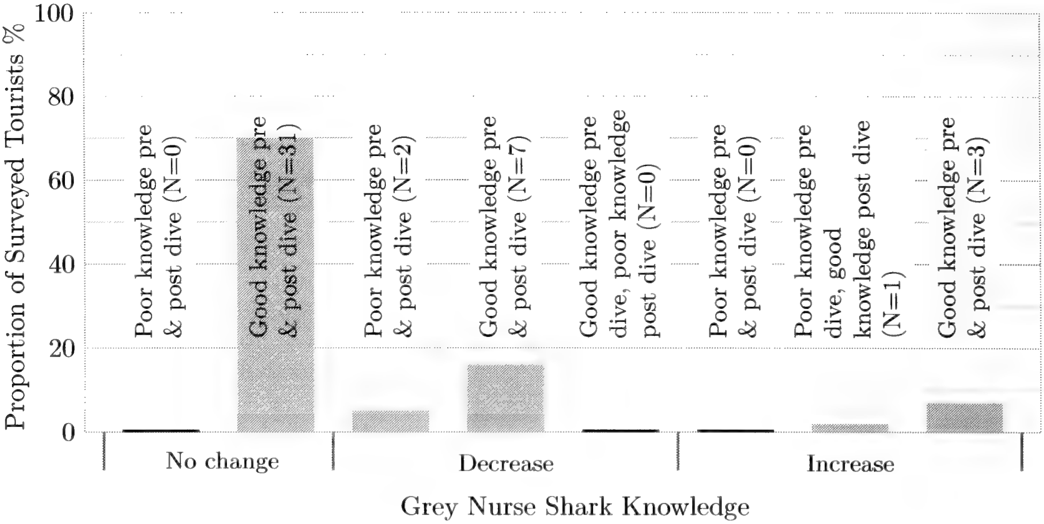


Figure 8. Proportion of surveyed tourists (%) per category (i.e. poor knowledge pre dive or good knowledge pre dive) who either experienced no change, a decrease or an increase in knowledge post participation in a grey nurse shark dive (n = 44).

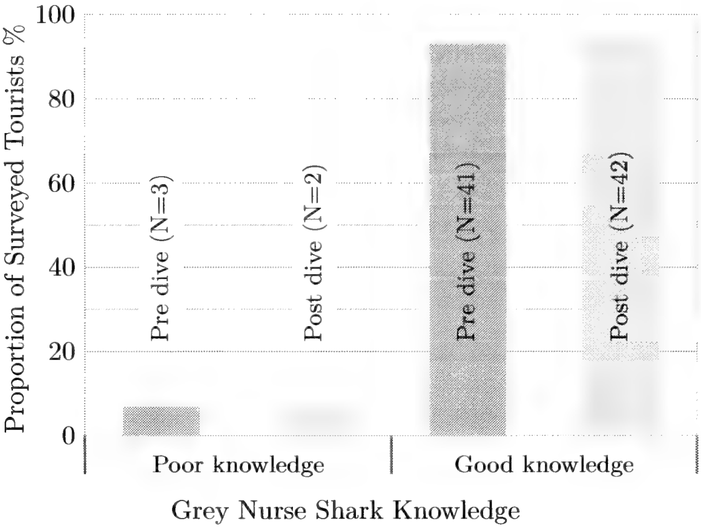


Figure 9. Proportion of tourists (%) possessing poor knowledge and good knowledge pre and post grey nurse shark dive (n = 44).

The proportions of tourists who answered the knowledge questions and statements correctly pre dive and post dive is presented in Figure 10 (the phrase 'grey nurse shark' is abbreviated to 'GNS' in Figure 10). For 28.6% of the knowledge questions and statements the provision of the correct response increased post dive (i.e. 'grey nurse sharks are an endangered species', 'can a tourist diver touch a grey nurse shark?'); for a further 28.6% of knowledge questions a decrease in the provision of correct answers was documented (i.e. 'is the population size of grey nurse sharks at an acceptable level in eastern Australia for their long term survival?', 'are grey nurse sharks a threat to humans?'); therefore, for the remaining 42.9% of the knowledge questions and statements the proportion of tourists who responded correctly did not alter post grey nurse shark dive (i.e. 'grey nurse sharks are a protected species', 'can a tourist pursue grey nurse sharks?', 'are sharks an important part of the marine environment?').

Figure 10 indicates that 80% or more tourists provided correct responses both pre dive and post dive to all but 1 of the knowledge questions and statements (i.e. 85.7% of questions and statements). The proportion of tourists who answered the remaining question (i.e. 'is the population size of grey nurse sharks at an acceptable level in eastern Australia for their long term survival?') correctly pre dive was 66% and this amount decreased to 59% post dive.

Comparison of Post Grey Nurse Shark Dive Survey Responses of those given an Educational Talk & those whom were not

Biocentric Statements

A Mann-Whitney test found that there was not a significant difference (α=0.05; $0.01<P(U\leq317.5)<0.02$) between the biocentric survey responses of tourists whom were provided with an educational talk and those whom were not. Therefore, the null hypothesis that the provision of educational talks does not improve biocentrism within tourists post participation in a grey nurse shark dive should be accepted.

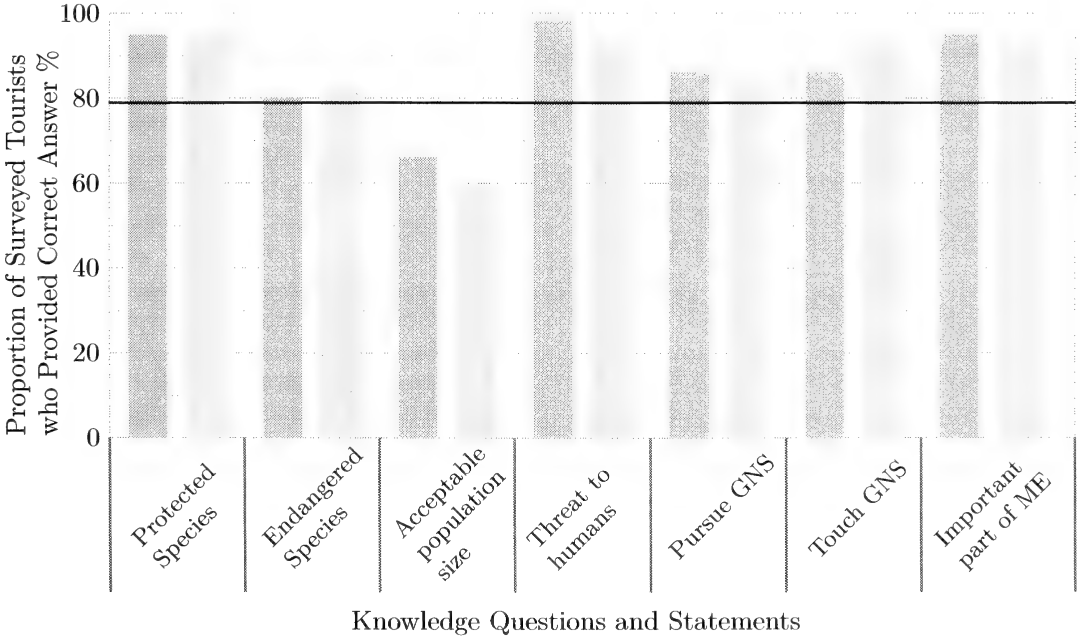


Figure 10. Proportions of tourists (%) who answered knowledge questions and statements correctly pre dive and post dive. GNS = grey nurse sharks, ME = marine environment, n = 44. The point at which responses are deemed biocentric is indicated by the thickened black line. Pre dives Post dives

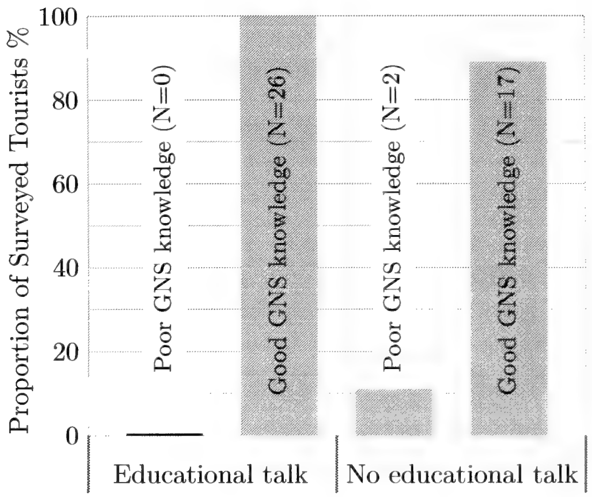


Figure 11. Knowledge of surveyed tourists provided with an educational talk and of those not provided with an educational talk (n = 45, GNS = grey nurse shark).

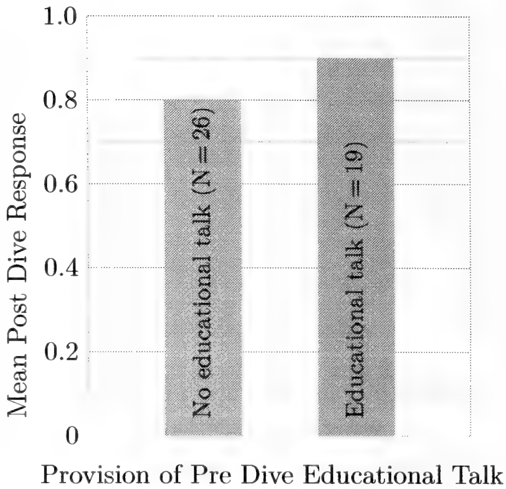


Figure 12. Mean post dive survey response to knowledge questions and statements of tourists provided with an educational talk and of those whom were not provided with an educational talk (0–0.4 = poor knowledge, 0.5–1 = good knowledge, n = 45).

Knowledge Questions & Statements

Mann-Whitney test results indicated that there was a significant difference (α=0.05; $0.01<P(U\geq494)<0.02$) between the post dive knowledge survey answers of those present for an educational talk and of those who were not. Figure 11 (the phrase 'grey nurse shark' is abbreviated to 'GNS' in Figure 11) shows that 100% of tourists that were provided with an educational talk possessed good grey nurse shark knowledge post dive. Of the tourists whom were not provided with an educational talk 89.5% were considered knowledgeable post dive and 10.5% were deemed to have poor grey nurse shark knowledge. Therefore, the provision of an educational talk appeared to increase the proportion of tourists who had a good level of grey nurse shark knowledge by 10.5%.

The mean response to the knowledge questions and statements post dive of tourists provided with an educational talk and of those whom were not are presented in Figure 12.

It can be seen from Figure 12 that the mean response to the knowledge questions and statements of tourists whom were provided with an educational talk was 0.9, which indicates a greater level of grey nurse shark knowledge compared with tourists whom were not provided with an educational talk, whose mean response was 0.8. Hence, a 12.5% increase in the mean post dive response of those tourists whom were provided with an educational talk was documented.

DISCUSSION

Nature-based tourism has the potential to benefit conservation by improving pro-environmental attitudes and environmental knowledge within tourists (Ballantyne et al. 2008, Zeppel & Muloin 2008). In addition, it has been found that provision of education during nature-based tourism experiences can further enhance these benefits (Hughes & Saunders 2005, Christensen et al. 2007, Powell & Ham 2008, Zeppel & Muloin 2008). Results of this study indicated that both positive and negative influences were exerted on the

biocentrism and knowledge of tourists (short-term) who participated in a grey nurse shark dive at Fish Rock, New South Wales. Although an increase in biocentrism was documented post dive, the majority of this improvement occurred in tourists that were deemed biocentric pre dive. Furthermore, the decreases in biocentrism reported only occurred within pre dive biocentric tourists. In addition, the improvements to and decline of knowledge that were documented occurred largely within tourists that already possessed a substantial degree of grey nurse shark knowledge prior to their dive experience. Therefore, it is necessary to discuss current results holistically (rather than focusing on individual results in isolation from each other) and the probable reasons behind them to prevent their misinterpretation.

Previous research (Hughes & Saunders 2005, Christensen et al. 2007) investigating the influence of nature-based tourism on pro-environmental attitudes and knowledge within tourists has suggested that prepossession of such views and values may be partially (if not wholly) responsible for the apparent lack of sway that tourism has in increasing pro-environmental attitudes within participants. The same could account for the minimal (although significant) increases in knowledge documented in this and Morris et al.'s (2007) study. In addition, it has been surmised that whilst the ability of tourists to recall and relay facts presented to them during a nature-based tourism experience may indicate improvements in their short-term knowledge, it does not necessarily signify that they personally agreed with the information or that the knowledge gained in turn positively influenced their attitudes towards the target species and conservation (Hughes & Saunders 2005). Tourists' perceptions of the target species, environment and the tourism experience itself may also influence the level of knowledge attained from participation in nature-based tourism activities. Hence, in situations where educational resources supplement the nature-based tourism experience, the content and quality of the resources (whether they be presentations, informal talks, interpretation materials or otherwise) appear to be of utmost importance to ensure that the desired information and messages (relating to management guidelines, conservation and so forth) are effectively communicated to tourists (Mayes et al. 2004, Ballantyne et al. 2008, Zeppel & Muloin 2008, Mayes & Richins 2009). In order to facilitate maximum conservation benefits through the provision of education and to prevent the potential for further misconceptions to arise if tourists seek additional information from other sources (for example, the media, documentaries, books and so forth), it is proposed that the information provided during tours is consistently reviewed and updated to ensure its accuracy.

Whilst biocentrism increased in 29.8% of survey participants a large proportion (57.1%) of this improvement occurred in tourists previously deemed biocentric prior to the dive experience. In a study on a whale watching education program in Oregon, Canada, Christensen et al. (2007) noted that the increase in biocentrism of tourists who participated in the program compared with those who did not may have been attributed to the likelihood that people with strong existing biocentric attitudes were more likely to participate in and be more receptive to the program compared with those of weaker biocentric orientations. Similarly, Morris et al. (2007) concluded that although the manatee knowledge of boaters who participated in a Manatee Watch outreach program was quite high, boaters who did not participate in the program also exhibited a high degree of knowledge. This notion is of great relevance to the results of the current study. Whilst the overall proportion of biocentric tourists did not increase as a result of participating in a grey nurse shark dive nor was an increase documented as a result of the provision of an educational talk (i.e. educational talks did not significantly influence biocentric views), an increase in biocentrism was detected. This was due to the large proportion (78.7%) of tourists who were already deemed to be biocentric prior to the dives; hence whilst their level of existing biocentrism could improve, only 21.3% of tourists had the potential to shift from neutral views and values to biocentric attitudes. Furthermore, 14.9% of tourists obtained a 'perfect

score' of biocentrism (i.e. answered 'strongly agree' to all eight biocentric statements) pre dive and so no improvement could take place.

Similarly, although a small proportion (9.1%) of tourists experienced an improvement to knowledge post dive, 75% of these tourists were already deemed to possess good levels of grey nurse shark knowledge prior to the dives. A total of 93% of participants were considered to hold good grey nurse shark knowledge pre dive experience, so the group of tourists most in need of knowledge improvements (i.e. those with poor grey nurse shark knowledge) represented only 7% of the grey nurse shark divers. In light of these results, it is suggested that the premise that nature-based tourism presents real benefits to conservation by encouraging people to become more environmentally aware, concerned and knowledgeable may not be entirely valid as it appears that those likely to participate in such activities generally already possess these qualities: a finding supported by the results of other studies (Christensen et al. 2007, Morris et al. 2007). Hence, the conservation benefits to be gained from improving the biocentrism and knowledge of participants via nature-based tourism may be minimal. It is therefore suggested that in order for conservation to derive maximum benefit from positive shifts in biocentrism, non-biocentric and neutral individuals need to be the target demographic. However, the feasibility of this is dubious as such individuals would require not only a preparedness to finance such an experience but also a willingness to participate in an activity that may not particularly appeal to them (due to the possible absence of a certain degree of interest in the environment and the focal species).

Furthermore, a significant increase in the proportion of tourists with good grey nurse shark knowledge was detected in tourists provided with an educational talk compared with those whom were not. The inclusion of the correct responses to the knowledge survey questions and statements in the educational talks and the use of visual aids containing important facts may have prompted the retention and recollection of this information post dive (Hughes & Saunders 2005), regardless of whether tourists personally believed in the validity of them. This is reflected in results, which indicated that improved knowledge does not parlay into an improvement in overall biocentrism.

Lastly, when viewing each knowledge question individually it becomes apparent that the perceptions developed by tourists during their dive experience may be an important factor determining the accuracy of their responses. For example, a 7% decrease in the proportion of tourists who correctly answered the question 'is the population size of grey nurse sharks at an acceptable level in eastern Australia for their long term survival?' was documented. Prior to the dives, many tourists may have been informed (via media, scientific literature, educational talks as a part of the current study, or elsewhere) that the east Australian population of grey nurse sharks consists of approximately 300–500 individuals and is a critically endangered stock (Environment Australia 2002). However, during their dive experience some tourists may have encountered a large amount (counts of 30 or more individuals were not uncommon) of grey nurse sharks in the one area (i.e. Fish Rock) which could have led to the false assumption that the population status of grey nurse sharks is not as low as they previously believed it to be. Further support for this notion exists in the post dive responses of tourists to the question 'are grey nurse sharks a threat to humans?'. After participating in a grey nurse shark dive the proportion of tourists who incorrectly believed that grey nurse sharks are a threat to humans increased by 5%. Again, this may be attributed to tourists' visual perceptions of grey nurse sharks (i.e. large, strong animals with sharp, protruding teeth) when viewed in close proximity and the associated connotations. Therefore, the potential for tourists to adopt inaccurate perceptions as a result of their experience must be identified so that such inconsistencies are demystified via education programs or interpretation resources both pre and post nature-based tourism experience. In addition, it is of utmost importance to evaluate such programs to ensure that the content conveys important information and assists in the development of appropriate perceptions of the target species.

Future Management

In light of the potential for incorrect perceptions to cause a decline in the knowledge of tourists, it is clear that the content and quality of educational and interpretation resources are important factors when assessing the sustainability of nature-based tourism endeavours. Specifically in relation to the grey nurse shark dive industry at Fish Rock, it is important that tour operations clarify with tourists that whilst they may encounter a large number of sharks during their dive experience, Fish Rock is an identified critical habitat site (Environment Australia 2002) and thereby does not represent an accurate portrayal of grey nurse shark populations elsewhere along the east coast of Australia. In addition, such resources need to be developed in situations where they are currently absent.

Further research of the extent to which nature-based tourism activities positively influence the pro-environmental attitudes of tourists (and hence, benefit conservation) is required before industry allowances are made based upon this assumption. This is particularly pertinent when allowances are made for tourism settings of which the focal species is critically endangered. In addition, research investigating the causal links between improved knowledge and biocentrism within tourists is recommended.

CONCLUSION

This research demonstrated that nature-based tourism has the capacity to both promote and hinder pro-environmental attitudes and improve knowledge within tourists. It is probable that greater increases in both biocentrism and knowledge were not documented due to the high proportion of tourists whom were already considered biocentric and knowledgeable prior to their dive experience; hence, the scope for improvement was narrow.

ACKNOWLEDGEMENTS

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Thesis Abstract: Towards a New Philosophy of Engineering: Structuring the Complex Problems from the Sustainability Discourse

DONALD HECTOR

Abstract of a Thesis submitted for the Degree of Doctor of Philosophy
School of Chemical and Biomolecular Engineering, The University of Sydney.

This dissertation considers three broad issues which emerge from the sustainability discourse. First is the nature of the discourse itself, particularly the underlying philosophical positions which are represented. Second, is the nature of the highly complex types of problem which the discourse exposes. Third is whether the engineering profession, as it is practised currently, is adequate to deal with such problems.

The sustainability discourse exposes two distinct, fundamentally irreconcilable philosophical positions. The first, "sustainable development", considers humanity to be privileged in relation to all other species and ecosystems. It is only incumbent upon us to look after the environment to the extent to which it is in our interests to do so. The second, "sustainability", sees humanity as having no special moral privilege and recognises the moral status of other species, ecosystems, and even wilderness areas. Thus, sustainability imposes upon us a moral obligation to take their status into account and not to degrade or to destroy them. These two conflicting positions give rise to extremely complex problems. An innovative taxonomy of problem complexity has been developed which identifies three broad categories of problem. Of particular interest in this dissertation is the most complex of these, referred to here as the Type 3 problem. The Type 3 problem recognises the systemic complexity of the problem situation but also includes differences of the domain of interests as a fundamental, constituent part of the problem itself. Hence, established systems analysis techniques and reductionist approaches do not work. The domain of interests will typically have disparate ideas and positions, which may be entirely irreconcilable.

The dissertation explores the development of philosophy of science, particularly in the last 70 years. It is noted that, unlike the philosophy of science, the philosophy of engineering has not been influenced by developments of critical theory, cultural theory, and postmodernism, which have had significant impact in late 20th-century Western society. This is seen as a constraint on the practice of engineering. Thus, a set of philosophical principles for sustainable engineering practice is developed. Such a change in the philosophy underlying the practice of engineering is seen as necessary if engineers are to engage with and contribute to the resolution of Type 3 problems. Two particular challenges must be overcome if Type 3 problems are to be satisfactorily resolved. First, issues of belief, values, and morals are central to this problem type and must be included in problem consideration. Second, the problem situation is usually so complex that it challenges the capacity of human cognition to deal with it. Consequently, extensive consideration is given to cognitive and behavioural psychology, in particular to choice, judgement and decision-making in uncertainty.

A novel problem-structuring approach is developed on three levels. A set philosophical foundation is established; a theoretical framework, based on general systems theory and established behavioural and cognitive psychological theory, is devised; and a set of tools is proposed to model Type 3 complex problems as a dynamic systems. The approach is different to other systems approaches, in that it enables qualitative exploration of the system to plausible, hypothetical disturbances.

The problem-structuring approach is applied in a case study, which relates to the development of a water subsystem for a major metropolis (Sydney, Australia). The technique is also used to critique existing infrastructure planning processes and to propose an alternative approach.

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Thesis Abstract: Geological and Geophysical Evaluation and Interpretation of the Blantyre Sub-basin, Darling Basin, New South Wales

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Abstract of a Thesis submitted for the Degree of Doctor of Philosophy,
University of New South Wales, Sydney, New South Wales, Australia

This thesis presents a study of the Blantyre Sub-basin, which covers an area of approximately 14,000 square kilometres in the central part of the Darling Basin, western New South Wales, extending from latitude 31°55′ to 32°45′ South and from longitude 143°00′ to 144°10′ East. A large amount of geological information and geophysical data have been evaluated to carry out a regional study of the Blantyre Sub-basin, with the purpose of reconstructing its stratigraphy, sedimentology and structural evolution. The study has followed an integrated approach, using lithostratigraphy, chronostratigraphy, sedimentary lithofacies, regional tectonic elements, gravity, seismic profiles and wireline logs, as well as core, cuttings and outcrop data, to evaluate the Devonian sequence. This study demonstrates the use of seismic cross sections to assist in the interpretation of stratigraphic successions. In addition, the analysis of lithofacies generated from well studies has been used to support the interpretation of the subsurface geology from the seismic data. The study involved three main approaches.

Firstly, synthetic seismograms (one-dimensional) were constructed from the available well data and used to compare the well geology to the seismic response at the well locations. The results were used to identify the primary reflector interfaces, to confirm the stratigraphic boundaries, and to identify possible multiple reflections in the seismic data. Application of the synthetic seismogram technique in this study has been shown to be an effective tool in linking well logs to seismic data. A new stratigraphic correlation of the Winduck, Snake Cave and Ravendale Intervals has been suggested for the Darling Basin. The stratigraphic boundaries of the intervals were defined at marked changes in well log characteristics, and the depth estimates of the boundaries were derived from the well log information (especially the data for Mount Emu-1, Blantyre-1, Booligal Creek-1, Booligal Creek-2 and Kewell East-1). Seismic cross-sections were constructed as an extension of the synthetic seismograms, and involved modelling of the whole time section using the well data as control. They were used to identify the geometry of the key reflectors, and to study the vertical and lateral variations in the key stratigraphic horizons. The horizons recognized in this study ranged from the top of the undifferentiated Proterozoic complex/Ordovician sediment? to the base of the undifferentiated Cenozoic sediments, but the main part of the study was focused on the Devonian sequence of the Winduck Interval and the Mulga Downs Group (Snake Cave and Ravendale Intervals). The seismic cross-sections were used to map the variations in structure and thickness of the Devonian sequence, and also of the overlying Upper Carboniferous or Permian sediments. They also provided indications of seismic features such as changes in amplitude at the tops of basement highs, and pinch-out of some stratigraphic horizons (e.g. Winduck, Snake Cave and Ravendale Intervals) when traced in the seismic sections.

Secondly, sedimentological analysis was applied, using lithologic samples (cores and cuttings), petrographic studies, wireline-log and seismic profile information, to aid in the development of a geologic model for the Mulga Downs Group in the Blantyre Sub-basin. Based on its geometric pattern and internal lithofacies

distribution, the Mulga Downs Group displays, both in vertical and lateral sections, three different lithofacies successions. The lower part of the Mulga Downs Group (Snake Cave Interval) is a succession mainly composed of braided fluvial and meandering fluvial lithofacies, with minor fluvial-shallow lacustrine complex lithofacies and the upper part of the Mulga Downs Group (Ravendale Interval) contains braided fluvial and meandering fluvial lithofacies passing upwards into estuarine tidal channel deposits and a nearshore lithofacies complex contemporaneous with a near shore braided-delta plain complex lithofacies. Seismic facies analysis was also applied to some of the seismic profiles, comparing well log observation with reflection configuration and other seismic characteristics for the Winduck, Snake Cave and Ravendale Intervals. The seismic facies patterns show continuous, semicontinuous and discontinuous reflections with moderate amplitude and high to moderate frequency. The unit identified from the well data can also be recognised in the seismic profiles, with features such as low-angle and high-angle clinoforms, parallel and sub-parallel reflections and a few hummocky/wavy reflections indicating scour or secondary channel-fills, shallow channel-fills, and small-scale fluvial channels.

Thirdly, a three-dimensional geological model was developed from the seismic data to map out the geometry of the key reflectors, and hence the structure and thickness of the Winduck, Snake Cave and Ravendale Intervals in the areas where these intervals have been preserved. This model has also better defined the Wilcannia High, and two smaller highs around the Mount Emu-1 and Snake Flat-1 wells. The results have also been compared with the gravity contour map of the area, to further describe the relationships between the various lithostratigraphic units.

Isochore maps for each lithostratigraphic (in two-way travel time) have been compared to the travel-time structure contour patterns, especially for the Winduck and Snake Cave Intervals, to identify any thickening and thinning associated with structural development. Additional seismic cross-sections were also constructed to assist the analysis process, further investigating relations between the stratigraphy, sub-basin geometry, and the development of complex structures within the study area.

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Thesis Abstract: An Investigation on the Use of EGR in a Natural Gas SI Engine

AMR ALY HASSAN IBRAHIM

Abstract of a Thesis submitted for the Degree of Doctor of Philosophy,
University of South Australia

Internal combustion engine emissions are currently a major source of air pollution. The harmful impact of engine emissions can be reduced when engines are fuelled by alternatives to petrol and diesel such as natural gas. The use of lean burn technology in spark-ignition engines has been dominant; however, the lean burn technique can not economically satisfy the increasingly restricted future emission standards particularly for NOx emissions. In this thesis, the use of the stoichiometric air-fuel mixture with exhaust gas recirculation (EGR) technique in a spark ignition natural gas engine is investigated. The aim of the research is to optimize the key engine operating conditions in order to obtain the lowest NO emissions accompanied with low fuel consumption and high power. This is achieved via both experimental and computer simulation research.

Experimental research was conducted using a single-cylinder engine which was converted to run from petrol to natural gas and modified for EGR operation. The engine was fitted with necessary sensors and equipment in order to analyze the combustion process. Also, the engine was fitted with a supercharger and an intercooler. A computer simulation was also developed. This simulation was constructed based on the mass and energy conservation principles and the combustion process was analysed using a two-zone combustion model. The computer simulation was validated by experimental results at a wide range of operating conditions and a very good agreement between the results was achieved.

It was found that increasing the percentage of EGR in the inlet mixture has a significant effect on NO emissions. The increase of EGR dilution in the inlet mixture from 0 to 10% decreased NO emissions by about 70% at a compression ratio of 10 and atmospheric inlet conditions. The maximum percentage of EGR dilution that can be used to achieve the lowest NO emissions was found to be about 10, 12, and 15% at compression ratios of 8, 10, and 12 respectively. It was also found that the use of EGR dilution prevented surface ignition and knock occurrence at higher inlet pressures and compression ratios which improved engine performance. For instance, the increase of inlet pressure from 101 to 113 kPa at a compression ratio of 8 and EGR dilution of 10% increased engine brake power by about 26% and decreased engine brake specific fuel consumption by about 7%. On the other hand, the increase of compression ratio from 8 to 12 at atmospheric inlet conditions and an EGR dilution of 10% increased engine brake power by about 11% and decreased engine fuel consumption by about 10%.

When both EGR and air dilution strategies were compared at the same conditions, it was found that the EGR strategy slowed down the combustion rate more significantly which resulted in lower power and higher fuel consumption compared to the use of air dilution at the same conditions. However, when the EGR was investigated at higher inlet pressure, engine performance was improved. For instance, employing EGR at a percentage dilution of 15% and inlet pressure of 111 kPa resulted in achieving equivalent fuel consumption and about 9% increase in brake power compared to the use of 15% air dilution at an inlet pressure of 100 kPa.

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Scholarships

The Council of the Royal Society of NSW funds the Royal Society of New South Wales Scholarships in order to acknowledge outstanding achievements by young researchers. Applications are considered from PhD candidates, enrolled in a university within New South Wales, who have completed at least two years of candidature by 30 April. There is no restriction with respect to field of study within the sciences and up to three Scholarships will be awarded each year. Applicants must be Australian citizens or permanent residents of Australia.

The Scholarship Awards for 2009 were presented on Wednesday, 2nd December 2009 at St. Paul's College, University of Sydney.

Maintaining the Genetic Diversity of the Tasmanian Devil: Development of Assisted Reproductive Technologies

TAMARA KEELEY
Faculty of Veterinary Science, University of Sydney and Taronga Conservation Society of Australia.

The steep decline in population of the Tasmanian devil has lead to research into species preservation through artificial insemination of cryopreserved spermatozoa. Tamara has developed methods to improve sperm viability and motility after cryopreservation. Tamara's research also includes the study of reproductive and stress hormones in the faeces of captive female devils.

Molecular Interactions and Chirality

ISA CHAN
School of Chemistry, The University of New South Wales.

Chirality, or 'handedness', is the structural characteristic of a molecule that cannot be superimposed on its mirror image. It is essential to the proper functioning of living systems. Devising more efficient methods in the generation of chirally pure compounds has been of great interest in contemporary chemistry and beneficial to many key areas of science. Isa's current research involves systematically revealing new types of weak non-covalent interactions. An alicyclic diol example will be presented, whose structure is determined simply by the solvent chosen for crystallisation.

Spatial Cognition and Foraging Ecology of the Noisy Miner

DANIELLE SULIKOWSKI
Department of Brain, Behaviour and Evolution, Macquarie University.

Danielle has investigated the spatial cognitive abilities of the noisy miner bird. She found that the natural distribution of rewards can be used to predict the variation seen in the birds' performance and strategies they use to complete tasks. Danielle's experiments were based on the assumption that cognitive mechanisms, as the proximate determinants of behaviour, have been shaped by evolution, to allow animals to behave in functionally adaptive ways.

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Biographical Memoir

Maren Krysko von Tryst
1921 – 2009

Our colleague Maren Krysko died on the 26th June 2009 and we were able to celebrate her life at her committal on the 7th July 2009. Maren suffered a stroke some two years before her death, but with typical perseverance make few compromises to her affliction. The service was led by the Reverend Mark Schultz of the Epping Lutheran Church. The service was attended by people who knew her and had worked with her throughout her very productive life here in Australia, as well as friendships from her many other interests.

Maren Gerda Meta Anneliese Krysko von Tryst was born on 21st July 1921 in Hameln in Lower Saxony, Germany. She had a younger sister Ute, born in 1925. Her father John Paulsen was an engineer who worked on railway construction and her mother was Asta Wahrendorf born in what is now Lithuania, which before World War I was a thriving part of Germany. John Paulsen was from the small island of Föhr in the North Sea, one of the islands in a group that are collectively known as Friesland. Friesland is the home of sailors and adventurers and was in early Medieval times a powerful and influential Kingdom. The Kingdom contained parts of modern Denmark to the north, and modern Holland to the south. It has another distinction it that its language is the root from which the English language developed.

On Amrum, the near neighbor of Föhr, accessible by walking at low tide from Föhr, the cemetery at the largest village Nebel contains many Paulsens who were Ship Captains and maritime adventurers. It was with this rich heritage that Maren most strongly identified, an identification that was reinforced by spending many idyllic summers as a child on Föhr where she established life-long friendships with her many cousins.

It was Maren's misfortune to be born into 'interesting' times. The family lived in Berlin and she obtained her matriculation at the Studienanstalt Fürstin Bismark Schule in Charlottenberg in 1939. She began studies at the Technische Höchschule Berlin-Charlottenberg in 1940. At the same time she was required to work in a lead factory until 1944, presumably on war material production. John Paulsen was required to work on rail projects in the east and was considered a valued asset to war transport. At this time the German railways were being straightened to win time in the transport of materials to the Eastern Front. Rail was a strategic asset, ranking with energy production in priority.

Maren married Vladimir Krysko in 1941. Vladimir was an Engineering Graduate of the Technical University. In the closing stages of the war Maren and her husband were evacuated to the Harz Mountains where they were 'liberated' by the American Army in 1945, followed by some very difficult times in Displaced Persons Camps. Maren and her husband were fortunate to be considered as Berliners, as the Berlin Airlift in 1948 had as a parallel policy the removal by migration of excess population from Berlin. All the Allied countries cooperated and in 1948 Maren and Vladimir were accepted by Australia. They became members of a select group, the very first Germans to migrate to Australia after World War II. The next were the many skilled workers recruited in the period 1950–54 for the Snowy Mountains Scheme.

In Australia Maren worked as a technical assistant for the South Australian Department of Mines. Maren and Vladimir's only child Marina was born at Port Pirie in 1950. The family moved to Sydney soon after, and Maren worked with CSIRO in the Division of Radiophysics. She took up her studies again at the University of NSW. Her husband held an academic position at the University of NSW at the same time. She and Vladimir divorced in 1957, and later Vladimir returned to Europe to live in England. At a later time Marina left to study and joined her father in England, and continues to live there.

Maren graduated with a Bachelor of Science majoring in Geology in 1962. She obtained a Post Graduate Diploma in Mineral Technology from the School of Mining Engineering UNSW in 1965. She was employed in 1964 by the School of Applied Geology as a Tutor and with the School of Mining Engineering UNSW where she was involved in post-graduate programs.

Maren had a passion for teaching and this combined with her passion for Earth Sciences led her to become a very respected and authoritative figure in Earth Science education. She was very demanding of the students, and at the same time encouraging. She joined a select group of University teachers who operated at the Tutor/Demonstrator level to become the backbone of the faculty. She eventually became a Principal Tutor.

First year students often try a course, and if they find it to their liking they will be recruited into the discipline. A major factor is the presentation of the course and the passion and commitment of their instructors. The University owes a debt to Maren, as she inspired many a student to pursue Earth Sciences. She therefore joints such indominables as Maude McBriar who was a similar institution at Adelaide University in Geology, and the never-to-be forgotten Miss Nichols at the University of Sydney who inspired at least two generations of Physics students. To be such a person is a real achievement in itself, but Maren was even more.

In 1952 Maren was a foundation member of the Geological Society of Australia NSW Division. In 1963–64 she served as a council member and treasurer. During the 1960s Maren became involved in numerous scientific organizations such as the Association for Women Graduates NSW Division, and the Australian New Zealand Association for the Advancement of Science. The contributions she made to these organizations are well remembered, but the most remembered and honored was her involvement with the Royal Society of NSW.

It was in 1960 that Maren first joined the Royal Society. Maren became the Honorary Secretary (Editorial) and continued to work for 35 years in the production of the Society's Journal. The Journal was edited and published on time for all the time she held the position. The fortunes of the Society hit some very low levels, but doggedly and persistently she battled on. At one stage it was suggested that the Society be discontinued, but that notion was soon put aside in the face of opposition from Maren that can only be described as Formidable. Please note the use of a capital F at the beginning of the word Formidable. At one stage she was faced with finding a home for the Society and all its chattels, closure of the Society and pressure to modernize the Society's procedures. She struggled with all, and therefore became the champion that secured the future of the Society, albeit changed into the functional, more established institution that it is today. We thank you Maren, even those of us who at times were the focus of your wrath.

A high point in the Royal Society's recent history was to mount Summer Schools for High School students. This was Maren's special task, and the interesting programs she put together year after year contributed to young people being recruited into scientific careers, and if not so, led to take a deeper appreciation of modern science into their non scientific callings. She labored at the summer schools with the same dedication and need for excellence which she brought to her University teaching..

On retirement Maren chose to live alone as she had for a good part of her life, taking pleasure from her frequent trips to visit her daughter Marina resident in England as well as the numerous cousins and other more distant relatives in Germany. She had a passion for Genealogy and worked diligently on her Frieslander family tree. She was also active in matters of heritage, and was frequently seen on Sunday outings with various groups on walking tours of historic precincts around and in the city.

My fondest memories are of this lady-with-a-mission, who would visit us many a sunny afternoon, we were only a few doors away, and choose to sit on our front veranda wanting to discuss issues that had come up in the news. She was always very interested in local issues and in some instances could be described as an 'activist'. She was always sharp and to the point, but logical and incisive with a tendency to become rather impatient if faced with 'fuzzy' logic or half considered ideas. As time passed she talked of her personal journey, and we came to have a deeper appreciation of the experiences this lady had been trough. Many were unpleasant, so we came to have an understanding of why and who she was.

My wife was concerned that if she ever had a medical problem, she might be not found for a time because of her living alone. My wife and Maren started a system that involved an envelope in our letter box at least once a week, and as time went by, some years in fact, we were treated to clever little illustrations, short whimsical poems, and seasonally comments such as facts about Easter and Christmas. We received hand made Christmas and Easter cards, and my wife was always remembered by small gifts when she went on her trips back to Europe. That is the way our family wants to remember Maren. She was our friend.

Maren Krysko von Tryst was a treasured Australian and we are grateful that she came to live amongst us and contribute so much to our personal lives and to our Australian way of life. We thank her and honor a life that was lived with passion, was lived to the full without compromise, even unto the last.

Rest in Peace Maren, you are well remembered by those who knew you.

Dr Robert A. Creelman
October 2009

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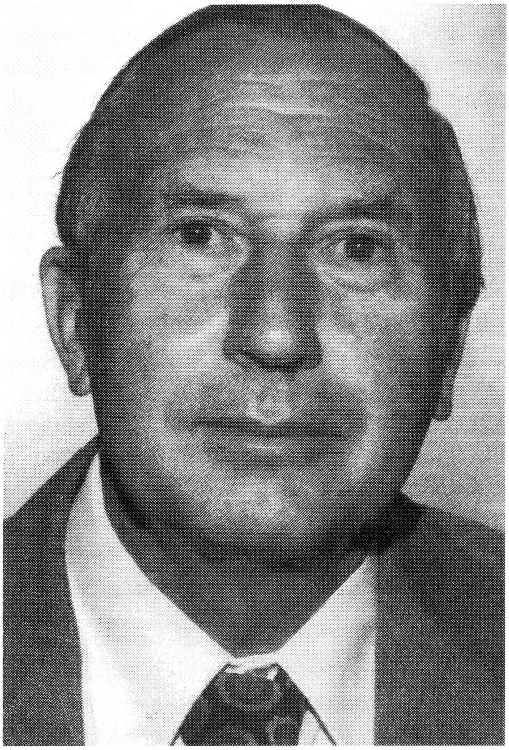
Biographical Memoir

Howard Hamlet Gordon McKern
1917 – 2009



Howard McKern was born on 23rd March 1917 in Mosman, Sydney. He was educated at Newington College, Stanmore, Sydney, passing the Leaving Certificate Examination in 1934 with First-Class Honours in Chemistry and Geology. He obtained his Diploma in Chemistry from the Sydney Technical College in 1942 as well as, at the same time, studying physiology, microbiology and botany. He was awarded the degree of Master of Science by thesis from the University of New South Wales in 1957.

Howard spent ten years (1936–1945) working in organic and analytical chemistry in the Parramatta chemical laboratory of Meggitt Ltd. eventually being promoted to Assistant Chemist. In 1945 he joined the staff of the Museum of Applied Arts and Sciences in Ultimo as Head of the Museum's Chemistry Department directing its research on the chemistry of essential oils. He was appointed Deputy Director of the Museum in 1960 and remained in this position until his retirement in 1977.

He was elected Member of the Royal Society of New South Wales in 1943 and served as its President in 1963. He was the author as well as co-author of some 40 research papers (12 in the Journal and Proceedings of the Royal Society of NSW), chiefly in the fields of the chemistry and chemotaxonomy of essential oil-bearing plant species. In addition to several biographical articles on some of his predecessors at the Museum of Applied Arts & Sciences, he contributed a chapter in the Centenary Volume of the Royal Society of NSW on the Research into the Volatile Oils of the Australian Flora, 1788–1967. He also published a biography of his maternal grandfather 'William Mogford Hamlet (1850–1931), Gentleman and Scholar', a distinguished chemist employed in the NSW Public Service. In recognition of his work the Royal Society of NSW awarded him in 1968 the Society's Medal for Services to Science and to the Society.

He joined the Royal Australian Chemical Institute in 1942 and was elected Fellow in 1957. He also was member of the University of New South Wales Chemical Society, as well as its President in 1960–1961, and was awarded in 1945 the Society's George Wright Prize. He served for many years as a member of the Essential Oils Committee of Standards Australia, including 9 years (1968–1976) as its Chairman. He represented Australia in 1976 at the Lisbon meeting of the Essential Oils Committee of the International Standards Organisation where he succeeded in blocking an attempt by Portugal and Spain to exclude Australian eucalyptus oils from the definition of eucalyptus oil, thus saving our eucalyptus oil industry from potential extinction.

Howard was also an active member of several museum oriented organisations, such as the Museums Association of Australia (Member 1958, Associate 1974, member of Council and two terms as President: 1974–75 and 1975–76 and Editor of the Association's Journal 'Kalori'). He was also Editor of the NSW Branch Quarterly Newsletter (1975–1977). In 1979 he was conferred the Honorary Fellowship of the Association. He was appointed member of the Australian Committee for Museum Staff

Training set up under the aegis of the Australian National Commission for UNESCO (1973); the Board of Studies within the Faculty of Arts for the Post-Graduate Diploma in Museum Studies (1975); Chairman of the NSW Cultural Grants Committee on Museums and Galleries etc. He was awarded the Queen Elizabeth II Silver Jubilee Medal 1977 for community service.

But Howard was more than a respected scientist and competent administrator. His interests included music, literature, history and art. He studied drawing, painting and drawing under well-known teachers and exhibited his works at a number of galleries. In 1952 he was elected Exhibiting Member of the Royal Art Society of NSW. His exceptional mastery of the English language was reflected in the clarity and style of all his writings. Howard's language skills also found expression in his ability to speak fluent German.

I remember him as a knowledgeable, courteous and friendly colleague. Despite his official function as the Museum's Deputy Director he found the time to take his morning tea with us in the Museum's chemistry laboratory, discuss on-going projects and plan future essential oil research projects. He loved the Australian bush and occasionally took part in our plant collecting trips. On such occasions his knowledge of botany was of incalculable help. His knowledge and comments on the geology and colonial history of the areas we visited made these trips a real treat.

His last years were bedevilled by failing health, loss of eyesight as well as hearing and finally cancer. He passed away on 7th June 2009, aged 92 years.

He will be remembered by all his family and friends, like his forebear, as a 'Gentleman and Scholar'.

Erich Lassak (from personal acquaintance)
and generous advice from his wife,
Mrs C. (Lollo) McKern

NOTICE TO AUTHORS

Manuscripts should be addressed to The Honorary Secretary, Royal Society of New South Wales, Building H47 University of Sydney NSW 2006.

Manuscripts will be reviewed by the Hon. Editor, in consultation with the Editorial Board, to decide whether the paper will be considered for publication in the Journal. Manuscripts are subjected to peer review by an independant referee. In the event of initial rejection, manuscripts may be sent to two other referees.

Papers, other than those specially invited by the Editorial Board on behalf of Council, will only be considered if the content is substantially new material which has not been published previously, has not been submitted concurrently elsewhere nor is likely to be published substantially in the same form elsewhere. Letters to the Editor and short notes may also be submitted for publication.

Three, single sided, typed copies of the manuscript (double spacing) should be submitted on A4 paper.

Spelling should conform with 'The Concise Oxford Dictionary' or 'The Macquarie Dictionary'. The Systéme International d'Unites (SI) is to be used, with the abbreviations and symbols set out in Australian Standard AS1000.

All stratigraphic names must conform with the International Stratigraphic Guide and new names must first be cleared with the Central Register of Australian Stratigraphic Names, Australian Geological Survey Organisation, Canberra, ACT 2601, Australia. The codes of Botanical and Zoological Nomenclature must also be adhered to as neccessary.

The Abstract should be brief and informative.

Tables and Illustrations should be in the form and size intended for insertion in the master manuscript – 150 mm x 200 mm. If this is not readily possible then an indication of the required reduction (such as 'reduce to 1/2 size') must be clearly stated. Tables and illustrations should be numbered consecutively with Arabic numerals in a single sequence and each must have a caption.

Half-tone illustrations (photographs) should be included only when essential and should be presented on glossy paper.

Maps, diagrams and graphs should generally not be larger than a single page. However, larger figures may be split and printed across two opposite pages. The scale of maps or diagrams must be given in bar form.

References are to be cited in the text by giving the author's name and year of publication. References in the Reference List should be listed alphabetically by author and then chronologically by date. Titles of journals should be cited in full – not abbreviated.

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